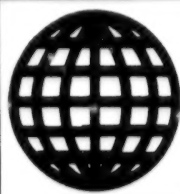


JPRS-EST-95-006
15 February 1995



**FOREIGN
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JPRS Report

Science & Technology

***Europe/International
Germany:
Review of Research in Information Technology***

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Science & Technology

Europe/International

Germany: Review of Research in Information Technologies

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Germany: Review of Research in Information Technologies

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1. Introduction

[FBIS Translated Text] In view of the extraordinary significance of information technology for economic and social development in Germany, in 1989 the Federal government presented its policies and the most important relevant fields in a future-oriented plan. The inter-departmental "Plan for the Future of Information Technology" agreed on by the Federal cabinet provides a programmatic framework for further development of the conditions for the application of information technology and for supporting a broad and future-oriented palette of information technology products and services.

In this plan for the future, the Federal government indicated the decisive role played by information technology for the international competitiveness of our economy and for social development. Information technology products are essential in Germany for the most important investment branches which provide funding for the majority of exports. This analysis has found more and more confirmation. Information technology, and the powerful communications infrastructures built on it, have become an essential element of modern industrial societies. They represent a decisive factor in economic standing and offer particularly great opportunities for growth and for the creation of jobs with promise for the future.

In information technology, industrial creativity and product innovation are linked with the continued development of innovative base technologies, with research for new system solutions, and with the achievement of scientific groundwork for the application of new information technology products. The BMFT [Federal Ministry for Research and Technology], starting from evident technical and social developments, presented the working priorities for research in its "Funding Plan for Information Technology 1993-1996." (Cp. "Report of the Federal Government on Measures and Outcomes of Its Policies in the Area of Information Technology," Bonn, September 1993)

In its plan the BMFT offered incentives with regard to contents and financial funding measures which would permit the individual initiative of science and the economy to develop. What is suggested is a mutually harmonious progress of the state, science and industrial

research. Strategic pilot projects and research alliances between institutes of higher education, non-university research and industry will set the agenda for research and development which will aim at marketable products and a broad application of them.

Rapid progress in information technology leads to changes which require quick reactions from research policy during the term of the funding plan. The present report presents what has been achieved after a two-year working phase and draws conclusions for reorientation of target areas for the funding agenda. Among the important starting points are recent BMFT analyses on scientific and technical prospects for the future, as well as results of the innovative dialog on many levels with representatives from the economy and science instituted by the BMFT.

The basis of the BMFT's wide-ranging initiatives is the vision of the "information society of the 21st century." Information technology plays a key role in the development of modern societies. It penetrates all spheres of economic and social life, is a vital prerequisite for continuing environmentally friendly growth and for the creative utilization of information as a new resource. The high-profile role of information technology as a crossover technology which is significant for many other technological fields is the rationale for the basic strategic position of research and technology policy in Germany. (Cp. "Perspectives for Research and Technology Policy in Germany," Bonn, 15 July 1993)

2. Information Technology Funding

2.1 Significance of Information Technology for Assuring the Future

All analyses of Germany's international competitiveness agree that research-intensive fields have shown growth rates far above the average over the last ten years, both in production and in number of jobs, in comparison with non-research-intensive fields. Particularly in overcoming structural weaknesses in the German economy, it is true to say that Germany's future will be determined by investment in knowledge-intensive fields and thus by the efficient and creative utilization of knowledge and information. More than any other technical development, information technology offers the requisite means and methods for this. Likewise, all economic predictions assign a key role to information technology internationally, and give it pride of place at the beginning of the 21st century, far ahead of other technologies, with respect to market growth and developmental dynamics. These predictions are based on a doubling of the 1992 world market volume by the year 2000 in information technology, from about \$1,000 billion—not including communications services and media. The percentage of the gross national product made up of information technology products will rise to about 10 percent by the year 2000. The strong dynamics in the development of information technology will continue uninterrupted.

A further aspect underlies the particular significance of information technology. The durability of development, protection of resources and reduction in environmental stress are important criteria for political negotiation and for business leadership. This reorientation towards a constantly forward-looking development brings central ideas into the foreground, such as

- material and energy efficiency
- creative utilization of information and efficient application of knowledge
- awareness of nature and application of biological principles

Instead of earlier products, which were frequently materially oriented, we find knowledge-intensive solutions to problems with a large amount of information and communication technology and software and improved utilization of information. Thus information technology offers the conditions for growth, high-paying jobs and employment, competitive industries and efficient administration, as well as for a clean environment and protection of resources. Information is a resource and should be available everywhere at the proper time and in the appropriate format. Its creative utilization requires advanced information infrastructures, which are particularly significant as a factor in industrial standing and for ensuring international competitiveness in knowledge-intensive products and services.

In the manufacture of information technology products, both German and European industry occupy a relatively weak position in important areas of international competition. The share of German companies in the total production of information technology goods is 6 percent. In the case of microelectronic components, only half of the rapidly rising demand is covered by German suppliers. On the other hand, Germany is particularly strong in the application of information technology products and in the working out of solutions for complex intelligent technical systems, in specialized software and procedures based on information technology. Such fields include auto electronics, communications technology, chip cards, mobile radio, automation and microsystem technology, and standard operating software.

With the emergence of the information society of the 21st century, it is particularly important for German science and the German economy to use the opportunity to eliminate weaknesses and to build on current strengths. The center of attention at the moment is transfer- and application-oriented goals and the broad utilization of information and communication technologies.

2.2 Funding in the Field of Information Technology

The "Information Technology Funding Plan 1993-1996" sets the overarching goal of maintaining and enhancing Germany's role as an attractive site for research, development and production of information technology goods and services and their utilization, as

well as to seek innovative ways of better utilization the strengths of the level of research for Germany's economic standing in information technology. The position of German science should be supported and current strengths of application-oriented research should be built up to the extent that the economy also supports it as promising for the future. Particular weight is given to the interaction between information technology and medicine, biology, environmental and climatological research and traffic technology. Another important task is to achieve a closer mesh between the researches in state research institutes and in industry and to encourage the transfer of results of research to competitive products, processes and services.

The essential measures are derived from these strategic goals:

- The kickoff of new areas of knowledge through project funding in an alliance of science and industry, particularly in interdisciplinary fields of information technology/mathematics-physics-biology-chemistry (this finds its expression in new base technologies and information projects such as bioinformation technology, photonics II, neural networks, pattern and speech recognition, genetic algorithms and evolutionary strategies, molecular electronics, nanoelectronics/quantum structures, 3-D integration, biosensors, medical technology microsystems, etc.).
- The funding of pilot projects and model pilot applications with broad potential for application: electronic eye, mobile speech translation (VERBMOBIL), supercomputers, telecooperation, HOFFNUNG (information technology and biology for human beings), information technology in transport, environment and health.
- The support of strategic community projects between science and the economy in fields of the future with clearly transfer and application-oriented objectives: DAB [Digital Audio Broadcasting], JESSI [Joint European Submicron Silicon Initiative], digital HDTV [High-Definition Television], parallel processors, microsystems technology, smart fabrication (flexible chip factory of the future), display technology.

Funding goals focus on satisfying the present and foreseeable needs of a modern society. The earlier approach, which was predominantly technology-oriented, was transformed into a solutions-oriented focus on funding projects which address current and projected application fields in Germany and on the international market. Examples of important application perspectives are given in Chapter 3.

Important instruments and methods to achieve these strategic goals include the following:

- joint projects between science and the economy, possibly with early involvement of potential users;

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- increased programmatic focus of research institutes on the long-term requirements of industry (e.g., potential analysis of state research by ZVEI/VDMA [Central Association of the Electrical Engineering and Electronics Industry/German Machine and Plant Construction Society] in the field of information technology and influence on R&D program planning of research institutes by representatives of industry);
- evolution of research funding in the R&D programs of the European Union as a subsidiary contribution to national support of research and development;
- strengthening of the innovative dialogue between science, business and policy-makers on several levels to define strategic joint projects (e.g., microelectronics, photonics and software technology for promising applications, utilization of microsystem technology, of high-power computers, etc.).

In filling out the outlines of the funding plan, several new funding targets and programs were set in motion in 1993-94, such as

- molecular bioinformatics/evolutionary algorithms;
- telecooperation, value-added services;
- VERBMOBIL;
- photonics II;
- high-performance computing;
- nanoelectronics;
- electronic eye;
- telecooperation (POLIKOM);
- microsystem technology 1994-1999;

Others are in preparation. Public announcement of these programs has met with strong resonance in science and business and has in every case led to promising new joint projects.

Information Infrastructure

Against the background of increased international initiatives for the development of the information infrastructure with the slogan "Information Highways," the BMFT introduced planned projects on prospective communications technology on a photonic basis as well as more far-reaching activities. In addition, the EU Commission distributed corresponding suggestions to member countries in their white paper. A central bundle of measures is dedicated to the development of the infrastructure in the area of telecommunications. The BMFT is focusing its projects particularly on future uses of modern telecommunications infrastructures. The main focus is on improvement of efficiency in performing tasks, new profitable services and the use of the information component in conjunction with the new possibilities of telecommunications which arise from the blending of computer technology and communications technology on the basis of digital networks. This basic idea will be operationalized into projects to expand the knowledge network and into computer linkages both in pilot projects for better utilization of information and in

telecooperation with the goal of developing innovative services, safeguarding the jobs of the future in structurally weak regions and in rural areas, among others, and to make cooperation within and between business and administrative organizations more efficient. It is to be hoped that this will lead to positive effects for transport and the environment also.

Based on current experience and drawing on international indications from the U.S. and Japan and from the white paper of the EU Commission, "Growth, Competitiveness, Employment—Challenges in the Present and Paths to the Twenty-First Century" and the so-called Bangemann Group, the BMFT conducted a coordinating conversation called "Information Highways—Vision for Technology and Marketplace" on 24 May 1994. The goal of this expert discussion was to stimulate an initiative to bring the future actions of industry, the media, telecommunications companies and important users in business and science into relationship with each other, and to discuss complementary funding measures, questions of standardization and governmental conditions. Stress was laid on the necessity for making rapid, goal-oriented progress in the reform of DBP Telekom in order to strengthen the competitive position of Germany and to open up the explosively growing markets of telecommunications and innovative services. The Federal Minister of Research and Technology intends to make the topic "Information Highways for Research" the subject of a special initiative during the German tenure of the EU presidency. The newly initiated dialogue on innovation for information highways will be continued with the postal and telecommunications sectors and with the business sector.

Semiconductor Technology: Institute for Silicon Technology

One of the funding plan's primary goals is to contribute to a reliable supply of modern chips in Germany, free of manipulation, by supporting research and development in the field of semiconductor technology. Microelectronics is the decisive base technology of information technology which makes other technologies possible. Timely availability and broad use of its products will determine the competitiveness of the whole high-technology field. Laying the foundation stone for the new Fraunhofer Institute for Silicon Technology (ISIT) in Itzehoe, which will begin its work in 1995, marked a very important contribution to maintaining and enhancing Germany's standing in research and production. By funding the ISIT, the BMFT is significantly expanding the public research infrastructure and is also pursuing the goal of strengthening future technologies in northern Germany using the diffused effect of the ISIT on the economy in that region. It will assure access to the most modern technologies to the users of microelectronic products in industry and offers research capacities, particularly for mid-sized companies which cannot support their own long-term research. The building of ISIT means that the BMFT has given further clear

indication of Germany's standing in microelectronics. This initiative is accorded great weight because of the rapidly rising need for application-specific chips for growth industries such as telecommunications, chip cards, multimedia, mobile radio, autoelectronics, etc.

This new development is a challenge to industry and an opportunity to improve the German position in microelectronics. The decision of Siemens AG to build a "Center for High Achievement and Innovation" in Dresden which is unique in Europe, and the laying of the foundation stone on 6 June 1994, are important results of a positive development, and a clear proof of the practicality of the strategic goals of the information technology funding plan. Industrial projects can build on an excellent research infrastructure in microelectronics and its applications.

New Laender

The reshaping of the research landscape in the new Laender is another important structural change in the research landscape. The founding of four new institutes from the Blue List and seven institutes or branch offices of institutes of the Fraunhofer Society in new Laender and the development of the standing of the Society for Mathematics and Data Processing in Berlin/Adlershof means that new, competent partners for discussion and cooperation exist for German industry in the area of information technology, e.g., in the fields of ASIC's [Application-Specific Integrated Circuits], manufacturing automation and software technology. In total, non-university state research for information technology was expanded by about 1,000 researchers. This effective research infrastructure forms a support for the structural change in the industry. Besides guaranteeing industrial fields for communications and information technology and microelectronics in the new Laender which are capable of development, it also contributes decisively to the strengthening of the high-technology field which is still backward here.

In the technical programs for information technology, the BMFT is supporting researches in the new Laender with over 100 million German marks [DM] annually. The inclusion of local research institutes and companies in joint projects for microsystems technology is gratifyingly frequent. Something like 70 percent of all projects of the program, which is specially designed to support cooperation between science and mid-sized businesses, involves partners from the new Laender. The use of modern microelectronics in small and mid-sized businesses is also supported by the construction of microelectronics applications centers in Erfurt, Jena and Chemnitz. The BMFT has underwritten the restructuring of industrial research capacities in the area of information technology and new construction in the amount of about DM160 million through its measures favoring research and development in the economy of the new Laender.

2.3 Dialogue on Innovation: Information/Communication/Knowledge

In the spring of 1994 the Federal Minister for Research and Technology began dialogues on innovation in various fields of application with experts from science and business. These form part of a continuing process of searching out new, important questions, in addressing which procedures of the various participants in the innovative process need to be tested. The technology-oriented approach of science and research is to be associated in this structure with the problem-oriented approach of business and society. The round of talks begun on 6 May 1994, "Information/Communication/Knowledge," combines established discussion topics of the BMFT with the results from the most recent studies and projections. Its goal is to define new, promising research fields and strategic projects together using an interdisciplinary viewpoint. In order to strengthen Germany's standing in research and business, information resources are to be made accessible for more rapid and efficient utilization by better linkage between supply and demand, by demonstration and pilot projects, by increased user-friendliness of equipment and by the further development of communication networks.

A further step was taken on 25 and 26 May 1994 in the context of the BMFT's efforts to analyze technological trends, to shape and accompany the discussion process on future scientific and technical developments and thus to obtain orientation for the revision of the funding plan. The main concern was the discussion of results of two investigations of the Institute for Systems Technology and Innovation Research of the Fraunhofer Society for the BMFT, the study "Technology at the Beginning of the Twenty-First Century" and the first German "Delphi Report on the Development of Science and Technology." Both studies revealed the many fields in which information technology can provide significant contributions either as the precursor of new base technologies, for innovative applications, for the solution of problems in communications technology, in transport, in production or in safeguarding health and environment. The discussion process includes the most recent position papers of the professional associations of the ZVEI and VDMA on the significance of information technology and on technologies of the 21st century.

The professional meeting confirmed the route to forming innovation policy and frameworks using consensus processes and using the state as moderator. The targeted areas for BMFT funding, such as micro- and optoelectronics, microsystems technology, new materials and applications, for example in environmental and transportation technology, were strengthened. Activities aimed at applications of new technologies were to be increased by "system-motivated projects," i.e., development of infrastructure and services. It would be possible to formulate an underlying concept for pilot projects from the theme of "information infrastructure." The results of this meeting are simultaneously being included in the innovation dialog.

Since the close of the Information Technology Plan for the Future for 1989, there has been a discussion group with business on information technology questions related to business technology; under the direction of the BMFT and the BMWi [Federal Ministry for Economics], with the collaboration of the BMPT [Federal Ministry of Posts and Telecommunications], various topics are taken under consideration in this group. In 1992, it was agreed to establish a "microelectronics" working group. The companies represented in it presented suggestions on safeguarding competitiveness of German semiconductor companies, their customers and suppliers in a consensus paper. The dialogue on microelectronics has been continued in a separate working group which includes more partners, in order to intensify the approaches to closer cooperation between companies and state-funded research in selected fields and to put these approaches on a broader foundation. The decision of Siemens AG in Dresden to start up a center for high achievement and innovation in Dresden drawing on state research potential already existing there is partially a result of intensive efforts of the BMFT in this discussion group to assure Germany's standing in the production of microelectronics.

In response to the situation regarding markets and competition in the field of telecommunications, a second working group on "telecommunications" has been started up. Its assignment is to analyze current problems in industrial policy in the field of telecommunications and to work out suggestions for negotiation possibilities.

At its meeting on 28 April 1994, the Petersberg group received the suggestions of business and science on a strategic joint project for the flexible automated chip manufacture of the future ("smart fabrication"). Further suggestions are in preparation on applications-oriented projects in microelectronics in the fields of transportation technology and the use of multimedia technology. These are also elements of the central innovation dialog of the BMFT and its effect on the research and innovation policy of the European Union.

3. Applications Perspectives

The example of microelectronics, as the base technology of information technology, shows how important new technologies are, particularly rapid transformation of new technologies into applications to accomplish long-term tasks. In contrast with earlier fears of the social costs of chip technology, it is clear today that this technology creates many promising jobs and makes a decisive contribution to the accomplishment of future tasks.

In the field of information technology, in the meantime, new base technologies in great number are standing ready. The main goals of the funding plan were therefore primarily intended to prepare the way for anticipated uses and to pursue predominantly system-related projects oriented towards a creative use

of the base technologies. The main targets of research funding should be determined by the prospective applications which hold out most promise for the future of society, business and the state. The progress achieved here for some prospective applications is presented in what follows.

3.1 High Definition TV (HDTV)

The funding of analog HDTV (high definition TV) came to an end with the expiration of the second phase of the EUREKA [European Research Coordination Agency] project on HDTV at the end of 1992. Since then the BMFT has concentrated its funding measures on the next innovative steps in the field of large-screen TV, which will be completely digital in the future. A joint project on "Digital HDTV" under the leadership of the Heinrich Hertz Institute in Berlin is devoted to this future task.

Since 1992, several companies and institutes have been working closely together in the HDTV group ("hierarchical digital television transfer"); its findings have attracted wide international attention. A particular focus of previous activities has been the area of digital image signal processing. Thus the Germans were able to be active participants in shaping the worldwide standardization process in this area (MPEG), based on the results obtained by HDTV. The digital multiplex which was created both standardizes the channel and receiver structures of HDTV and TV and also permits the digitalization of any image services and thus creates the connection between the worlds of television and the computer.

High-quality systems for entertainment electronics and computer technology (super HDTV, 3D TV, virtual reality), as well as inexpensive, easily manipulated, energy- and frequency-economical multiple services (interactive TV, audio and video on demand, mobile reception of graphic data services), including storage capacity for the required amounts of data, will only become possible through advances in image coding which far exceed the current state of the technology.

3.2 Digital Terrestrial Broadcasting

The EUREKA 147 DAB research project (digital audio broadcasting) is being developed in the current phase to be made ready for introduction. The results of the project, which are acknowledged and lead the way worldwide, were set down in 1993 in a comprehensive set of specifications which are now the object of European and international normalization through ETSI [European Telecommunications Standards Institute] and ITU [International Telecommunications Union]. For more than a year, the data-reduced tone coding developed in the project has already been established as a world standard in ISO/IEC [International Standards Organization/International Electrical Commission]. Numerous pilot experiments and demonstrations in ten countries have proved the great efficiency of the new broadcasting

system and led to the European (EBU) [European Broadcasting Union] and international (WBU) [World Broadcasting Unions] broadcasting organizations recommending that this system be used as a standard. The very critical question of the frequency band which is usable for DAB has so far found only a partially satisfactory solution. DAB can now begin to be introduced in the range around 225 MHz and 1.5 GHz; but the available band widths are not adequate for complete services. With these limiting conditions, at the moment the introduction of regular DAB broadcast services in the large industrial countries of Europe and particularly in Canada is being planned for about the end of the year 1995. The prototypes of the first IC generation are available from the JESSI DAB project as a chip set for receiving sets.

The project consortium was opened to the reception of new partners in 1993, in order to encourage worldwide acceptance of DAB. Since then, seven significant manufacturers of consumer electronics have joined the project, and 15 in all have declared their interest.

3.3 Telecooperation

Information technology opens up a broad spectrum of innovative products and new services which arise from the connection between computer technology and modern telecommunications on the basis of digital technologies and utilizing user-friendly human-machine interfaces. Telecooperation, i.e., cooperation which is based on advanced information and communications technologies independent of location, is of central importance here. It supports the general change from communication to cooperation, from the individual workplace to effective group work.

A further focal point is concentrated on new services in connection with efficient and creative utilization of the resources of information and knowledge. This is addressed particularly to structurally weak and rural regions, with the hopes of creating and safeguarding future-oriented jobs in them and of increasing the competitiveness of companies and dealing with the increased problems of transportation.

The central point of the funding target "Telecooperation/Multiple Services" started by the BMFT at the end of 1993 is the preparation for new forms of cooperation, information-based services and better utilization of information as a production factor, where the previous difficulty of the remoteness of a location is bridged by telecommunications. In five pilot projects (decentralized secretarial services, mobile company networks, information, language, management and consulting services) promising fields of telecooperation are being explored as a model, the new forms of working organization necessary for the utilization of information technology are being developed and possible obstacles are being discovered.

The second funding initiative, undertaken at the beginning of 1994, "Telecooperation POLIKOM," takes on the task of producing a better connection between the technical possibilities of information technology and immediate user needs in cooperation among non-local organizational units and between different organizations. The BMFT is funding the exploration of the support potential of new telecooperation technologies and making them user-friendly in three major joint projects so far, in which users, systems producers and science are working together. This is the prerequisite for future increases in productivity in businesses and administration through increased flexibility and networking.

The funding projects are intended to achieve an improvement in the application of telecooperation, which is underdeveloped in Germany by international standards, through user-oriented investigations and applications examples.

3.4 Biology and Information Technology

Data processing has an important function as a means of access and a mediator between biology and technology, first by making it possible to model, simulate and optimize biological processes and systems on the computer, and second by opening up new methodological approaches for applications in technical systems, inspired by biology.

The BMFT is funding innovative information technologies for use in molecular biology and biotechnology within the R&D target area of "Molecular Bioinformatics." New approaches to databank systems, optimization algorithms and data structures, as well as methods for artificial intelligence and neuroinformatics, are being worked out or further developed. The applications fields are in molecular design, in genome research and in the development of hormones.

With the funding target area of "Optimization Strategies in Bioinformatics: Evolutionary Algorithms," the BMFT is making a contribution to the solution of optimization problems which appear in almost all areas of the national economy, but can no longer be solved with traditional mathematical procedures because of their complexity. This includes problems involving combinatorics, such as in the planning of machine staffing, structure and parameter optimization in sequence planning and the evaluation of sensor data, and design tasks for many kinds of manufacture such as for objectives and the layout of circuits.

3.5 Information Systems for Safe and Environmentally Friendly Transportation

The great advances in microelectronics, sensorics, telecommunications and informatics clear the path for significant improvements in vehicle and transportation technology. They permit solutions which were previously not feasible or not practical for technical and

economic reasons. This includes systems in which electronic devices in the vehicle can be matched with roadside components (intelligent vehicles on intelligent streets). There is a whole sequence of approaches which are relevant for medium-term applications in transport from the recent research programs PROMETHEUS and DRIVE. The most important elements are collision avoidance, vehicle separation regulation, digitalization of transportation routes, cooperative traffic management, etc., all of which have been or are being funded in the BMFT's transportation research program.

Research fields for informatics which look farther into the future include particularly methods of mastering the complexity which is playing an increasing role in many other areas of business and technology, methods of developing complex security systems, of image recognition and processing and of interpretation of natural surroundings in transport.

In the funding area of applications for parallel supercomputers, new technological approaches to modelling, simulation and optimization of flow phenomena in vehicles and in combustion chambers are being supported with the goal of reduced energy consumption. Further technological approaches in this area concern the calculation of the vibrational stability of chassis using massive parallel computers. The results involve important contributions to the safety of vehicle passengers and to the minimization of traffic noise.

3.6 New Information Systems for Environment and Environmental Protection

Environmental applications are typically characterized by unusually extensive, heterogeneous and widely diffused data and information sets from biology, physics, chemistry, meteorology and every other technical discipline, often supplemented by information from business and administration. They must be collected, administered, evaluated and displayed. The models, procedures, methods and tools developed within the context of bio- and neuroinformatics, artificial intelligence and the area of massive parallel systems provide significant foundations for the effective treatment of questions in the environmental area.

3.7 German Research Network

The "German Research Network" of the DFN association, in which universities, state-funded research institutes and industrial research work together, has established and put into practice a nationwide communications infrastructure on the basis of manufacturer-neutral standards. Under the aegis of the EUREKA project COSINE [Cooperation for Open System Interconnection Networking in Europe], a technical harmonization of different national research networks was achieved, and a network was built up which connects these national networks with each other. In the past two years the activities of the DFN association have focussed

more strongly on the integration of the scientific institutes of the new Laender and of the countries of central and eastern Europe. Access to the scientific network of the DFN association was a decisive measure to achieve integration into the worldwide scientific community for the scientific facilities of the new Laender. Scientific data communications today are among the obvious and necessary prerequisites for successful scientific work. Through the German Research Network, scientists from the new Laender can now contact other institutes worldwide without any problem and can exchange news (electronic mail) and data and also hold conferences, research in databanks and use diffused computer capacities for their own work. In collaboration with the EU Commission, rapid data networks are to be set up for research in Europe, which offer improved access to information for science and industrial research.

4. Funding Target Areas

4.1 Submicron Silicon Technology

Microelectronics on a silicon (Si) basis is a key technology whose broad application and ready availability in the form of rapid, highly-integrated and complex systems, increasingly also multifunctional systems (i.e., combined with other microtechnologies) are decisive for the competitiveness of whole branches of industry. The developmental tasks have been organized according to target areas in the European JESSI program up to 1996, supplemented by content-related national projects in which companies and research institutes from the new Laender are particularly involved.

An example of complex applications systems based on the advances in Si technology and oriented towards a very broad affect in industry is the pilot project "Electronic Eye." New integration technologies should be regarded as alternatives to and extensions of monolithically-integrated Si microelectronics.

4.1.1 The JESSI Initiative

The main JESSI phase starting in 1992 marked a shift in the strategic target area to applications-oriented circuits for innovative systems solutions, in order to stimulate massive demand, in particular for ASIC's, in Europe. In 15 clusters with "flagship" joint projects and five individual projects, about 150 companies and research institutes with more than 2,500 researchers and engineers succeeded in cooperating across national boundaries in projects on semiconductor technology, chip applications and CAD [Computed-Aided Design] tools. The JESSI initiative has proved itself in spite of many critical remarks and changes in content, if only through the intensive cooperation of important areas of the European information technology industry and research landscape and the associated bringing in of achievements in cooperation with the U.S. (JESSI/SEMATECH). The

center of attention should be on transforming the scientific knowledge amassed in JESSI into economic successes for the participating companies. The annual volume of national German funding is about DM100 million. The developmental projects carried out in Germany amount to about a third of the total work done in JESSI for all participating countries.

Circuits for Applications

An example of systems-related applications projects is the JESSI cluster DAB (DAB = digital audio broadcasting). In this project, besides the development of an optimized circuit board for DAB receivers for mobile and stationary use, problems in electromagnetic compatibility were also investigated. The set of rapid and very highly integrated circuits will be available at the end of the main JESSI phase primarily in a 0.5 micrometer Si technology, and will be prepared for a further scaling of the structural measurements.

DAB closes the gap in digital terrestrial broadcasting with a quality corresponding to CD reproduction, so that now equivalent digital solutions are being offered for entertainment electronics for all signal sources in the audio range. This opens up a new mass market for the receiver industry in replacing the current analog UHF broadcasting.

Work on HDTV using the analog transmission system HDMAC for video has been discontinued. The surprisingly rapid development of data-reducing digital processes is accelerating the production of digital TV systems for satellite and cable reception and now also for terrestrial reception. Furthermore, completely new perspectives for integration are emerging in developments which link the fields of computer technology, communications technology and entertainment electronics (multimedia). The projects for more rapid and more highly integrated components for mobile communication systems have also been reoriented. The results in design methodology and actual production of security-optimized microelectronic systems (microcontrollers) promise to provide the basis for an innovative breakthrough, particularly for use in transportation.

Methods and Tools for Circuit Design

Here the key words are JESSI CAD frame (open design system at various levels of abstraction to incorporate individual design tools via standardized interfaces; JESSI/SEMATECH cooperation), processes and methods of modelling (e.g., transistor models with consistent orientation towards technological and geometrical parameters), test generation and "design for testability" and the synthesis of analog and digital systems (including hardware-software codesign) and electromagnetic compatibility.

European industry, which has access to advanced systems knowledge, took up more recent developments of system-descriptive languages immediately and focussed

their projects on them (VHDL [Very-High-Speed Hardware Description Language], AHDL). The results achieved in CAD development make it possible to demonstrate that in this field Europe's position can at least be defended on the international level. U.S. software continues to dominate this market.

Support for Small and Mid-Sized Companies

Within JESSI applications, we should stress the activities which are deliberately addressed to the acceleration and expansion of the use of microelectronics in KMU's (small and mid-sized companies). A well-known example is the SMI project (SMI = Small and Medium Size Industries) in which information is provided, improvements are made, and concrete systems solutions are produced for the broadest possible range of utilization in KMU's via SCC's (Support and Competence Centers). The project is closely associated with a list of similar European initiatives outside JESSI. Concrete projects in the JESSI environment for mid-sized companies in the new Laender (e.g., fuzzy chip sets, microcontroller and ASIC modules and other concepts for highly and very highly integrated circuits) support the constructive process in these Laender.

Manufacturing Technologies and Materials for Silicon Semiconductor Technology

In the field of equipment and materials, German industry today still has access in many areas to the potential to play a role in international competition and to help to shape workable concepts for the semiconductor factory of the future. In JESSI this is represented by the predominantly German initiative "Flexible Automated Wafer Production" (FAW-P).

Within a test platform, semiconductor manufacturing equipment, mini-environments, handling systems and supply systems and material distribution systems for liquid chemicals are tested, predominantly for German manufacturers. They were developed in various joint projects. In the areas of material distribution systems, local clean rooms ("transport boxes," SMIF [Standard Mechanical Interface]) and mini-environments an effective JESSI/SEMATECH cooperation was achieved. It is worth underlining the readiness of the equipment manufacturers to reach agreement on the general usability of the transport box systems to guarantee a linkage of production apparatus which requires few interfaces. Companies from the new Laender are associated with the FAW-P initiative, particularly in the area of automated quality control in the various stages of manufacture of structured wafers.

In the area of lithography, following on from the success of the I-line stepper on the world market, development was continued through DEEP UV-steppers (deep ultraviolet) for higher resolution; structures of 0.25 micrometers were reliably reached in experiments. This meant that the German market share could be maintained against their exclusively Japanese competition. The

results of the projects on wafer manufacture from molten silicon also made it possible for the participating companies to improve their position in the world market.

A significant result of the work on cluster tools and individual wafer processing has been the specification and demonstration of practical process sequences for modern production plans. The focus will have to be on projects involving in situ process measurement techniques and plant control. In general, projects on metrology (e.g., optical and "critical dimensions" metrology; integration of metrology into process modules and clusters) are being accorded increasing importance in universally optimized plans for future semiconductor production.

All German partners, with a large number of participants from the new Laender, are associated with JESSI in the joint project "Advanced Interconnection Technology," with the objective of replacing conventional conducting systems (AlSi) with systems with higher conductivity and electromigration stability (Cu). These projects are incorporated into European research via the ESPRIT project COIN.

Projects being funded on the requirements for purity in chemicals in the semiconductor process are improving cooperation between chemical and supply systems manufacturers and other equipment producers and semiconductor manufacturers.

4.1.2 The "Electronic Eye" Pilot Project

The pilot project (funding target area) "Electronic Eye" is intended to make functional principles and qualities of biological visual systems work (robustness, adaptability, real-time processing, compactness, flexibility, balanced capacities) and utilize them advantageously to overcome the performance deficits and limited applications of previous technological visual systems.

The long-term project on the development of new generations of technological visual systems is designed to create conditions for a lasting innovative breakthrough in the industry. It builds on current funding programs and complements them in order to open up and shape new application fields. German industry has a good position here with its powerful systems knowhow.

The tasks are highly interdisciplinary, e.g., with regard to:

- the development of new architectures for information processing (modular, open, multiply usable), which combine the properties of biological inspired (neural) and conventional processing methods,
- the development of effective and affordable systems techniques and technologies (sensor and VLSI [very large-scale integrated circuits] systems, new integration techniques, parallelism, networking), preferably determined by the technologies of microelectronics,

—the demonstration of systems advances within the application fields.

The challenge to industry to formulate their research and development needs according to these priorities led of necessity to the approach that rather than developing one electronic eye with all the relevant properties, specific solutions appropriate to each case are necessary. This approach increases the effective range of the "Electronic Eye" from the research community to many industrial and service branches in which technological visual systems are assuming an increasingly vital role for competitiveness.

The challenge to obtain suggestions for industry-led joint projects met with an extraordinary response and resulted in the following target areas for applications fields:

- automobile/transport: based on current national and EU projects; driver assistance systems with very high demands on the technical visual system predominate;
- inspection/quality control:
 - quality measurement: contact-free 3D real-time measurement of technological objects;
 - quality testing: texture analysis of flat and bent, technological and natural surfaces;
 - material sorting (recycling): recognition and classification of objects with extreme variation in form;
 - supervision: identification of living objects

Image-controlled diagnosis, manuscript and document recognition play a lesser role.

The projects are complemented by accompanying research on modeling of visual biological subsystems which is oriented towards applications-relevant recognition as a key function for nearly all joint projects.

Project leadership lies with industry, which draws non-industrial research institutes into the group and makes its own large financial contribution.

DM45 million are available to start the plan for the first three-year phase (1994-1996) of the long-term funding target area.

4.1.3 New Integration Techniques

In the last two decades the development of semiconductor technology and of very high integration for semiconductor storage (DRAM) led step by step to a fourfold increase in degree of integration every 3 years. With a time lag of about 3 years this technological development also gained a foothold in special circuits for signal processing. This trend will continue until the end of the 90's, although because of the ever-increasing financial costs for processing technology the cycle of improvement will slow down. The physical and technological limits for highly-integrated and highly efficient components with CMOS [Complementary Metal Oxide Semiconductor] technology lie in the range under 100 nanometers (probably in the region of 50 nanometers). There are now

more and more signs that the method of increasing system complexity through very high monolithic integration alone is more likely to reach an economic than a technical limit. Only a few international corporate alliances will be able to pursue this path. New integration techniques are therefore being investigated as technological alternatives offering enhanced prospects for microelectronic components.

Integration techniques in microelectronics have a high potential for development. Depending on the state of development reached in each case by traditional microelectronics, new components and principles can be discovered. Thus superposition and stacking structures in connection with other microtechnologies led to multifunctional systems. In addition, quantum electronic systems, molecular electronic systems and even biointegration technologies can be made use of.

The following pilot projects, which are regarded as particularly applications-relevant, are being carried out:

- surface hybrid integration as a multichip technology of independently produced individual chips, embedded in a silicon substrate and linked by technological advances in microelectronics;
- three-dimensional multichip superposition and stacking techniques, including cubic integration, in which greater system size and higher system complexity and packing density are achieved by components (chips) stacked on top of one another vertically in contact with one another or silicon hybrid-integrated modules;
- incorporation of microoptical, micromechanical or other structures in these technologies for multifunctional systems.

These projects in the technological area are taken on particularly by the institutes of the Fraunhofer Society (ISIT in Itzehoe, IZM [Fraunhofer Institute for Reliability and Microintegration] in Berlin, IFT [Fraunhofer Institute for Solid-State Technology] in Munich), supplemented by projects now in preparation which are concerned with the adaptation of CAD tools to these technologies.

The economic advantages of such new integration techniques are:

- the bringing together of independently produced chips with different technological and material basis;
- the opening up of new advances in integration by including the third dimension;
- the improvement of the balance of capacities of the integrated components;
- the more efficient utilization of expensive housing and sealing technologies;

—the introduction of technologies which are attractive even for smaller product runs.

The advanced level of the integration techniques based on the technologies of microelectronics permits further applications-driven development based on concrete industrial interests. They will first have to prove their worth in such complex projects as the "Electronic Eye" or in projects of rapid communications technology.

4.2 New Materials and Technologies

4.2.1 Microelectronics on the Basis of III-V Semiconductors

The III-V compound semiconductors, like gallium arsenide (GaAs) or indium phosphide (InP), are materials with increased importance for applications in electronics and optoelectronics. The ever-increasing need for information transmission makes an extension to higher frequencies necessary. New technologies on a GaAs material basis make it possible to use future systems up to about 100 GHz and open up new possibilities for future information technology.

There are more and more application areas in consumer electronics (DBS [Direct Broadcasting Satellite Service] and HDTV), in transportation technology (highly efficient traffic systems, vehicle separation warning radar, airfield supervision from the ground), in broadcast technology for commercial broadcast systems (directional and satellite broadcasting), and in environmental monitoring (radar systems with higher resolution, e.g., for earth observations). In opening up the enormous market potential of wireless communications the least expensive, i.e., monolithically-integrated production of micro- and millimeter wavelength circuits (MMIC's), is an urgent prerequisite.

The BMFT has taken this foreseeable development into account for quite a long time. The foundations for mastering the material and for the new steps in semiconductor processing which were required were first worked out in an initial funding program (1985-1990). Now research and development projects in the area of component and circuit technologies are being carried out, essential technologies for the key components for relevant applications e.g., in communications, environmental monitoring and for traffic safety systems. In addition, possible plans for completely new kinds of components for the next "millennium" are being considered and developed in the laboratory within the context of fundamental research. This project area is described in more detail in the section entitled "Nanoelectronics."

The cooperation between the partners within the III-V electronics group has proved very effective in accomplishing the extremely varied range of tasks. Some results are peak values internationally, such as the HBT [heterojunction bipolar transistor] for current/power increase at 90 GHz, the 0.3 micrometer GaAs HEMT [high electron mobility transistor] with a switching time

of 19 picoseconds, and the integrational density of a digital 16x16 multiplier which carries out 140 million multiplications per second and integrated 20,000 transistors on one chip with a surface requirement of 6x6 mm², a value which is only exceeded by one Japanese industrial lab.

With the III-V electronics joint program, the German semiconductor industry has obtained access to the headlong development in the sector of micro- and optoelectronic switching technology. The group's activities have also been a factor in the ability of the company Freiberger Elektronikwerkstoffe GmbH from Freiberg/Saxony to establish itself as a new producer of GaAs substrate material, the only one in Germany so far, in the bitterly contested world market for GaAs substratum production.

The leading European companies recently decided to cooperate more closely in GaAs technology. The goal is to develop an independent, competitive European GaAs technology. An initial European program is being funded within the framework of ESPRIT [European Strategic Program for Research and Development in Information Technologies] III. It is anticipated that a more comprehensive program will be set up in ESPRIT IV, with more German firms and institutes participating.

4.2.2 Nanoelectronics

The methods of achieving precision which have arisen in microelectronics have been developed to the point where lateral structures below 100 nm and vertical structures to the level of individual atomic layers can be reliably manufactured. In such structures the purely classical description of electron movement fails; the wave properties of the electron become more and more noticeable, i.e. quantum phenomena appear.

The possibility of exploiting quantum effects for extreme miniaturization of traditional circuits down to the nanometer range, of investigating individual electron phenomena and of achieving the theoretical information density of one bit per electron ("single electron memory") is fascinating; and it is already being predicted that the "quantum effect transistor" will open up completely new prospects for the semiconductor technology of the 21st century. The energy consumption and the chip surface of such a transistor could be reduced by orders of magnitude, accompanied by a dramatic increase in storage density up to the terabit range.

Nanoelectronics on the Basis of Compound Semiconductors

Such possibilities are being explored within the framework of the III-V electronics group on the material basis of III-V compound semiconductors. In the joint subproject "Mesoscopic Components," investigations on the physical bases of mesoscopic components are being funded (mesoscopic: the range between 0.1 micrometers and 1 nm), and at the same time the development of new

kinds of components whose functioning depends on quantum effects is also being funded. These include, for example, tunnel diodes as oscillators for very high frequencies with reduced power requirements and the in-plane gate FET [field-effect transistor], with a current-bearing channel which consists of a single one-dimensional electron gas.

In the joint subproject "Polytectonic Structuring Processes," projects are being funded which have as their objective the development of industrial technologies for very small structures with optimized integrability. The main focus is on the development of technologies which permit an in-situ combination of lateral and vertical fine structuring and thus provide the necessary conditions for the monolithic integration of different components (e.g. lasers and transistors).

The BMFT's funding is concentrated on the basic research, much of which is still required in this area. Cooperation between the joint partners from the institutes, the university milieu and industry should reveal whether the discoveries made in basic research make an application of nanoelectronics in very high frequency technology and communications technology attractive for the future.

Nanoelectronics on a Silicon-Germanium Basis

In the last few decades constant development in Si microelectronics has made it possible to master more and more precise measurements on semiconductor chips and to combine more and more functions on a single chip. Structures using individual atomic layers are being mastered in research already. In these dimensions, the classical laws on which microelectronics is based reach their limits; quantum effects must be taken into account. Thus, for example, electrons can tunnel through the thin layer of an isolator. This means that different physical principles are useful for creating entirely new components. Microelectronics becomes nanoelectronics.

Basic effects have already been investigated for gallium arsenide and its compounds and are well understood. But microelectronics is dominated by silicon, and on the possibility of integrating very different functions into a silicon chip. But silicon has weaknesses in dealing with very rapid components or use in optoelectronic applications. However, if silicon is combined with silicon-germanium semiconductor layers, components can be manufactured which work at very high speeds and can compete with other materials, e.g., in communications technology. There are even initiatives in basic research to be able to develop photonic and optoelectronic components on a silicon basis.

This conjures up the vision of putting conventional and very rapid components on a single integrated silicon chip and being able to combine them with optical transmission technology.

Activities in nanoelectronics have been significantly enhanced in Germany by the founding of the Institute

for Semiconductor Physics in Frankfurt (Oder). This Blue List institute with 150 highly qualified colleagues is being financed by the BMFT and by the Land of Brandenburg. Its main area of work is in the investigation of semiconductor structures on the basis of silicon-germanium crystals.

The BMFT has also undertaken an initiative by which it is hoped to achieve a promising critical mass for R&D capacity through funding of cooperation between higher education, Max Planck institutes, major research facilities and industrial research laboratories. Project funding will also make the previously scattered activities drawing on basic financing from the institutes, particularly their excellent apparatus, available for common objectives. So far about DM16 million have been approved for an initial three-year phase for projects which also have significantly expenditures by endowment and industry.

It is not the goal of the new funding measures of the BMFT to strengthen basic research in nanoelectronics, but rather to evaluate long-term application prospects. Therefore, electronic and optoelectronic components are central to the program from the outset.

A "Nanoelectronics" discussion group has been set up to coordinate the research projects; it will meet regularly for professional sessions. The group includes representatives from the leading basic researchers, and also from industrial users.

4.2.3 Molecular Electronics

The constantly rising demands for electronic components for use in information technology require smaller and smaller structures and more and more complex systems. But there are limits to the further ultra-fine structuring of today's semiconductor electronics. These are by no means all physical or technological in nature. Increasingly, there are also economic limits, beyond which very fine structuring in the classical mode, while technically possible, ultimately does not make sense any more at the moment because of the investment required.

The consequence is that future information technology systems cannot be manufactured exclusively on the basis of the established semiconductor materials. New technologies based on different material systems must be made available as well. In this regard the kinds of molecules provided by organic chemistry are particularly attractive, because they can be synthesized in almost unlimited variety and their properties can be purposefully changed.

Three joint projects on the topic of molecular electronics are currently being funded. The "Frequency-Selective Molecular Electronic Storage" group is working on the development of optical storage based on organic dye molecules. In contrast to current commercial optical data storage (CD-ROM, MO disc), here the information is stored in one place at different wavelengths, so that storage capacity is raised by the

socalled frequency multiplex factor. This is theoretically around 10^4 , but in practice a factor of 10 to 100 seems feasible at 77°K. The search for organic dyes which are usable at room temperature and the development of tunable semiconductor lasers at a suitable wavelength are of decisive importance.

Another group bears the title "Transport Phenomena in Polymer Substrate Boundary Layers: Characterization of Low-Dimensional Molecular Systems for Electronic Applications," and is concerned with the ordered growth of organic molecules on unstructured and structured substrates made of different materials. One focus of the work is the production of precisely regulated organic layers. Investigations which are relatively close to being put into practice are being carried out on the use of polyamides, instead of silicon dioxide, as planarizing isolation layers in semiconductor elements.

At the end of 1993, a third group was organized, with the title "Pattern of Self-Organized Molecules"; it began its work in 1994. The objective of this group is the electronic and structural characterization of organic molecules on the molecular level. Electronically active self-organized molecules which have organized themselves at selected boundary surfaces are synthesized in the project. Investigations on their manipulability in extremely distorting fields should reveal whether molecular patterns are suitable for molecular storage. The production of substrates with a relatively large surface area is particularly significant.

Projects in the field of molecular electronics are definitely still part of basic research at the moment. Rapid conversion to practical application is not anticipated. Nevertheless, research in this area is significant for the future, because this is a field in which significant breakthroughs to new technologies seem possible.

4.2.4 High-Temperature Superconductivity

The discovery of ceramic superconductors in 1986 with the possibility of employment at the temperature of liquid nitrogen (-196°C) made it necessary to reevaluate the use of superconducting components in microelectronics. The joint project "First Applications of High-Temperature Superconductivity in Microelectronics," which was initiated in 1990, represents the most significant national involvement to date in working out a technological base and in demonstrating electronic components based on high temperature superconductors. The results of the joint project were presented in March of 1994.

It has been proved that superconducting electronics possesses unmatched advantages in the sense of having the lowest electrical losses and the lowest noise in comparison with competing semiconductor circuits. In achieving the long-range objective of electronics with a very high level of integration and very high rates of information processing, integration cooling of the systems and the reduction of working voltage to well under

one volt will be of decisive importance. The time frame for getting such electronics to work should be measured in decades.

A much more immediate goal is the development of superconducting high-frequency and sensor technology with high-temperature superconductors, since the requirements for complexity and integrational density of the circuits are lower. The first rewarding application goals are signal processing in satellites with passive and active superconducting components, high-temperature distortion-free material quality control and non-invasive medical diagnosis using magnetic field measurements which give local resolution with superconducting quantum interferometers (SQUIDS).

The groups was able to achieve top-level results convincingly in international terms in displaying the potential of the new technologies with its demonstration models (highly functional SQUID's, high-frequency components). Techniques for circuit design, layering, structuring and device characterization were established.

In spite of all these successes in demonstrations, it must be remembered that up to now the technological developments within the group project and worldwide are still in the initial stages, with laboratory models which demonstrate functional principles, but are still far from being capable of meeting the criteria of production technology and business.

4.2.5 Photonics

Within the funding target area of photonics, scientists from industry, research institutes and universities have been working on topics in "Optical Linkage Techniques" and "Optical Signal Processing." The first phase of the project is ending after many years, to be followed by a second. The goal of the first phase was to investigate the fundamental possibilities of photonics and to demonstrate them in selected experimental systems as an example. It proved possible to achieve very good results. In the case of special lasers and optoelectronic detectors for information technology, as well as for optical fiber ring storage, international leadership was achieved.

The results obtained can contribute to maintaining the strong position of the German telecommunications industry. The orientation of the funding target area has proved to be right in comparison with international R&D activities. In regard to the anticipated need and the future demands on transmission and information processing systems with high bit rates and for optical linkage and communications technology, the available results have clearly exceeded expectations. Joint research has formed the basis for close cooperation between industry, research institutes and universities which has been consolidated through an intensive exchange of experiences in joint working groups and status seminars. The integration process for incorporating research institutes from the new Laender was successful and is largely complete.

Building on the findings of the first phase of the funding target area project, in 1993 the guidelines for a second project phase for 1994-1998 were worked out in close cooperation with industry. The projects will be oriented towards future applications in the sector of information communications technology. Some of its goals are information transmittal systems with very high bit rates, optical fiber enhancers for wavelength ranges which are not yet covered, optical communications systems and optical linkage systems for highly parallel linkage of circuits or computers.

4.2.6 Display Technology

Along with microelectronics, display technology is one of the most important key technologies for the whole field of information technology. Requirements include, e.g., large-area flat screens for entertainment electronics, screens for computers, telecommunications arrangements and trucks. Expert opinion holds that flat screens will replace cathode tubes, improve existing systems and almost make completely new products possible. Flat screens can be produced using various technologies; the most promising at the moment are liquid crystal screens (liquid crystal display, LCD).

Funding of display technology concentrated at first on the construction of an efficient research infrastructure. The Laboratory for Screen Technology was created at the University of Stuttgart in collaboration with the Land of Baden-Wuerttemberg. Here topics which play a role in display technology were comprehensively treated, from basic effects through homing in on individual screen locations and total displays to the complete manufacture of screen prototypes with all the necessary technological steps. This institute has developed into a center of competence for the industry here and abroad. In the field of large-area displays the institute is now able to manufacture full-color prototypes with a-Si-TFT and MiM homing matrices up to a screen diagonal of about 35 cm. These displays make the laboratory a leader outside of Japan and have given it a good name as a cooperating partner for industry.

Now that a European consortium of companies (Fiat Panel Display Co., FPD) has decided to produce active matrix LCD's, EUREKA activities for European industry are also getting underway, with an emphasis on strengthening the fields of materials and process technologies.

An alternative to LCD technology is being investigated in the Heinrich Hertz Institute, the field of electroluminescence. In this area, fundamental material investigations are being funded with the main focus being the development of blue emitters with a sufficiently high degree of intensity. Ultimately, the objective is application of the idea "color from white," and thus elucidation of the question of whether ELD's can in principle satisfy the requirements of large-screen color televisions. The

first working results have already yielded very promising emitters in the blue-green range.

4.3 Information Science Systems

Information science is the theoretical, experimental and constructive science of information-processing systems, particularly programming and utilization. In less than three years it has developed from a small scientific seed to a decisive factor with significance for many parts of the national economy and society. By now it has become a fundamental interdisciplinary science for most developments in science, research, education, economy, technology and public administration, and increasingly in private life.

Informatics funding within the framework of the Information Technology Plan for the Future concentrates on the following central tasks, which emerged partly from the knowhow and developmental prospects of German research, and partly from important challenges from the German economy:

- applications of knowledge processing, artificial intelligence,
- applications of very high-speed computing, massive parallel systems and parallel solution algorithms,
- applications of neuroinformatics,
- bioinformatics,
- software technology, security and reliability of informatics systems.

In the 80's, informatics funding had the job of supporting basic research and building up and maintaining the scientific landscape in higher education and research institutes. The successes of this funding are recognizable as the basis for and interdisciplinary function of many advances in business and administration. This is true of the areas of language processing, pattern recognition, knowledge processing, ultra-high-speed computing, and also software technology. These have created favorable conditions for greater practical utilization of basic results. Such an application of results is one of the decisive factors in determining whether the research results of other disciplines can be converted into useful applications.

Current R&D goals are derived primarily from concrete requirements for applications and are not centrally oriented towards basic informatics goals. This increased applications orientation has led to an intensification of cooperation with business, both major companies and KMU's, and thus to important stimuli for specific applications-related research tasks.

Applications-related basic research requires greater flexibility to be able to react to new international developments. This has been and is being taken into account with an increase in short-term and medium-term project funding.

Specifically, the target area projects and results of the individual focal areas can be characterized as follows.

4.3.1 Applications of Artificial Intelligence

The field of applications of artificial intelligence includes as its most important subdiscipline knowledge-based systems and machine recognition and understanding of images and language.

In the subarea "Knowledge-Based Systems," new processes and methods for knowledge processing are being investigated, e.g., the representation of knowledge on the computer (knowledge base) and inferential mechanisms. A general deficiency of previously developed knowledge-based systems is the limitation to a narrowly bounded area of competence and the inability to apply general knowledge unrelated to the task to find a solution.

Knowledge-based systems are funded by the BMFT in accordance with the target areas at the German Research Center for Artificial Intelligence (DFKI). The DFKI was created in 1988 at the instigation of the BMFT in Kaiserslautern with a further location in Saarbrücken. After a phase of professional and staff buildup, it has now reached full functionality and can already boast of research results in the areas of knowledge representation, computer linguistics and document analysis which are highly regarded internationally. A stage of stronger orientation of the work of the DFKI towards basic research with relevance to applications has begun.

Another important subarea of artificial intelligence is image comprehension, i.e., the interpretation of moving images or natural scenes. In the EUREKA joint project PROMETHEUS (PRO-A-RT) carried out under the leadership of the trucking industry, important research goals have already been attained in this area. It proved possible for a camera-steered experimental vehicle to travel a test stretch of the Autobahn at 100 km/h using purely visual route recognition. Since then, further automated achievements have been added, such as the recognition and avoidance of obstacles. In general, automatic recognition and interpretation of street scenes are intended to support and warn the driver in critical situations.

The third AI subarea includes the field of recognition and comprehension of written and spoken language. Genuine, internationally acknowledged breakthroughs in the recognition of continuously spoken language in human-machine dialogue were achieved with a joint project, SPICOS. The results of the project have been assimilated into later production developments for almost all the participating companies.

In current developments in the area of language processing one concern is integrating previously widely separated research in the area of speech recognition and language comprehension into a new architecture, in order to arrive at efficient systems. In addition, the research extends to the translation of spontaneous

speech utterances into a foreign language. The project VERBMOBIL is being funded in the hope that in the long term the goal of developing a workable translation system for spontaneous spoken dialog in negotiating situations will be achieved. The great interest of business in this project is the result not only of the direct goal of VERBMOBIL but also of many spin-offs, such as acoustic typewriters, data entry of all kinds, automatic translation of conversations or films, etc.

The funding area of artificial intelligence was recently evaluated by the firm of Arthur D. Little. As a result it was established that Germany has attained a scientific position in the last few years which is internationally acknowledged. On the other hand, the results so far on the transfer of knowhow are labeled as capable of improvement. Suggestions include greater applications orientation for future AI [artificial intelligence] funding. The BMFT is in the process of carrying out these suggestions.

4.3.2 Applications of Ultra-High-Speed Computing

The development of data processing in the next decade will be characterized by massively parallel computer architectures with thousands of processors. Computers of this kind promise an increase in power of a factor of 100 to 1,000 (teraflop computer) in comparison with today's vector computers (or fields of workstations). Business will profit significantly from these developments, since in future it will be possible for many experiments to be replaced by interactive simulations. While the corresponding hardware developments are being worked on constantly, with promising results, there is a definite need for R&D to catch up in the area of software, particularly in applications software, and in methods and tools to master massive parallelism. The BMFT began its initial funding phase in this area in mid-1993. The interest of business in this area was very intense. Initially, 16 major projects were approved. The applications target areas are in current dynamics, in mechanics of bodies, planning and processing in production and transport, molecular biology and chemistry, visualization technologies for medicine and predicting environmental processes.

4.3.3 Bioinformatics, neuroinformatics

The transition from classical sequential information processing to (fine-textured) distributed and parallel storage and processing of information in neural networks means that the particular ability of (data-driven) learning is linked with the possibility of associative supplementation of partial information through knowledge which is available in the system. Such flexible and adaptable systems are modeled on nature. They have very great prospects for applications.

This is the basis for a wide-ranging stage of joint research which has been going on since 1991, and in which

companies from the private economy are now also involved. The main topic of the joint undertaking is the development of flexible systems which explore their natural environment with various sensors and can act within it. R&D funding is now in preparation for a third stage, in which the kinds of R&D questions from the field of neuroinformatics which are necessary to solve questions about controlling autonomous processes are taken up.

Further learning effects taken from biology and molecular medicine are to be achieved within the framework of the bioinformatics funding begun in 1993. Attention will also initially be focussed on further development of information technology for applications in biology and medicine.

Molecular bioinformatics is a particularly rich source of innovative breakthroughs. With the use of special methods it is already possible to "read" the structural plans of whole organisms. The amount of molecular biology data which needs to be processed grows explosively in doing this. This is particularly true of the extensive genome projects being conducted worldwide. Here the task of bioinformatics is to offer new methods of data evaluation which permit intelligent access and effective management of large biological data banks. This created the requirements for unraveling all the genetic information (i.e., the genome) of individual organisms, which could lead to new industrial, medical, agricultural and ecological applications. Using predictions of the structure and function of proteins, a so-called "protein design" will be possible which equips proteins deliberately with new properties. In this way, medicines, injections, biosensors or materials with completely new properties can be developed. In 1993, a total of 8 major projects involving both science and industry were initiated in the above field of molecular bioinformatics.

Another direction of bioinformatics is concerned with the development of evolutionary algorithms, which describe optimization strategies drawn from nature. Evolutionary developmental processes which make it possible for an organism to achieve optimal adaptation to its natural environment for long periods of time could, after suitable adaptation, be converted into computer programs which are capable of solving complex optimization problems for which traditional mathematical procedures are ineffective. Such highly complex problems occur, for example, in system and circuit design and in machine staffing planning. Funding for this innovative subfield of bioinformatics was begun in 1994. The high level of interest which industry takes in this area, in spite of its theoretical nature, is made clear by significant participation in the projects.

4.3.4 Security and Reliability of Data Processing Systems, Software Technologies

Nowadays almost all areas of business and administration depend directly or indirectly on information processing. Thus funding of software technology and of

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security and reliability of informatics stems is an act of self-preservation for the state.

Important funding results over the last few years which have attracted considerable international interest have been in the field of new design of hardware and software for DV [data processing] systems from the perspective of the security and reliability of the systems instead of their power (REMO [reference model] project), the development of computer-testable and verifiable software on the basis of formal methods (KORSO project), and industrial labor-dividing software development analogous to classical production technology under the influence of quality control (ESF [European Science Foundation] project). A new funding focus which is in preparation cooperatively between business and the BMFT is oriented towards methods and techniques for modeling applications architectures as a basis for software development, towards methods of reusability and of reengineering of available software systems, and towards the further development of methods for producing secure and reliable software. In particular, it is hoped that this will contribute to mastering the complexity of large integrated software systems.

4.3.5 Data Processing Funding in the New Laender

Special support measures were implemented to include research groups from the new Laender in informatics R&D programs. Unfortunately the familiar problem arose, namely that there is no longer an industrial base worthy of the name in this region, so that up till now essentially only research groups from the colleges and universities of the new Laender could be included in the programs. Recently there have been several small companies which are trying to be included in funding. The BMFT supports this as far as possible.

A survey of funding of large companies, KMU's, colleges and R&D facilities in the field of informatics is found in Chapter 6.

4.4 Microsystems Technology

Microsystems technology will continue to offer far-reaching applications prospects in the 21st century. The BMFT has been funding the development of this technological field systematically and consistently since the beginning of the 90's with the funding target area "Microsystems Technology 1990-1993." Germany is now among the leaders in accomplishments in microsystems technology on the international level. Now it is important for the convincing successes of basic research and of applied research and development to produce marketable products.

In microsystems technology, components which "feel," "decide" and "react" are linked in technical systems which are characterized by miniaturization and built-in

"intelligence." Applications are found for them in manufacturing and processing (e.g., robot control), in transport technology (e.g., vehicle separation radar or knocking sensors for motors), in communications technology (e.g., television images without picture tubes), or in medical technology (e.g. flexible endoscopes for brain operations).

In 1993 seventeen joint projects with 76 subprojects were started. Thus, within the funding target area 48 joint projects with 300 subprojects have begun within 4 years. In the joint projects partners from industry and research work together on a goal. The companies receive DM102 million in funding. About DM115 million goes to university research institutes and others (see appendix).

In 1993 alone 33 companies and R&D facilities from the new Laender had joint projects with a volume of DM20 million approved. They have been most emphatically included in microsystems technology funding since 1990. About 70 percent of all joint projects involve partners from the NBL [New Federal Laender]. They receive over 20 percent of the Federal funds which have been approved for joint funding since that time.

Funding during the 4 years was accompanied by evaluation and assessment of the funding target area. Among other things, the recent category of companies and research facilities which deal with microsystems technology and their reactions to funding were analyzed. In contrast with the widespread opinion that small and mid-sized businesses would not participate in pre-competitive research and development, the very surprising finding was made that the small businesses in particular have a large share in joint funding. The 99 of 163 companies which have annual sales of less than DM50 million receive 53 percent of the funding which has been made available for industry.

A further result of this evaluation is that the majority of small and mid-sized businesses which undertook to develop complex microsystems were reached by this indirectly specific funding.

The mastery of this key technology is also a basis for the creation and development of jobs for highly qualified workers. For several years microsystems technology has been characterized by great economic potential which is produced by the linkage between various microtechnologies. Cautious estimates based on representative company surveys speak of a market of DM38 billion in the year 2000.

Small and mid-sized businesses usually do not have several different microtechnologies and the qualified workers required for each at their disposal. According to the evaluation, in order to meet the stringent requirements more and more cooperative efforts are being undertaken. Small and mid-sized companies prefer to bring in systems and engineering knowledge in components and develop competence from cooperation with research facilities. Large companies can tailor technologies and will try to mass-produce items together with small and mid-sized companies.

In addition, it is no longer sufficient to produce functions technologically; increasingly it is necessary to select the technologies and their linkage to one another in such a way that systems to be developed can also be produced economically.

The companies are making more and more use of the possibilities of drawing on resource centers for microsystems technology for consulting, know-how, facilities and results. Seminars, fairs, congresses and the who's-who data bank are used to bring partners together.

Evaluation and assessment have also shown that funded companies are more successful in controlling the more rapid innovation cycles which accompany demands for innovation. The development of innovation management goes hand in hand with an increase in the complexity of the projects to be implemented.

Building on prior funding experiences and the accompanying evaluation, last year over 600 interested parties from business and science, associations and boards were consulted in developing the new program, "Microsystems Technology 1994-1999." The funding program announced on 8 February 1994 by the Federal minister is focussed strictly on practicable results and thus contributes to the competitiveness of the companies.

The budget law anticipates DM102 million in funding for microsystems technology for this year, and current financial planning for 1995 anticipates a total of DM105 million, DM106 million in 1996 and DM108 million for 1997. This trend does justice to the increased international status of microsystems technology and its significance for preserving Germany's position. According to the cabinet resolution of 15 July 1994, project funding in the field of microsystems technology should rise to DM115 million in 1998.

The main emphasis of funding is on industrial joint projects in which at least two companies and one R&D facility are working together. Within industrial joint project the BMFT will place great value on the fact that the results of precompetitive research and development can be used without further intermediate steps as the starting point for project development by businesses.

Scientific pre-projects are being funded in the fundamental field of microsystems technology. The new accent on practically-oriented funding will be brought into play by the fact that the questions to be solved by the research institutes involved are set by the potential industrial users.

In the new program, foreign visits by scientists and engineers working in the field of microsystems technology can be funded with a travel stipend. Similarly, thorough analyses of quality control, organizational development and technology marketing are funded in order to achieve a broader diffusion of microsystems technology.

Large research institutes are increasing their involvement in microsystems technology. The first to take up the subject were the Fraunhofer institutes. By now they have provided significant funding from basic financing for microsystems technology; the association contributed DM18.5 million for this purpose in 1993. The major research center at Karlsruhe is following a similar path. In the research target area of microsystems technology up to DM60 million annually is to be used in the research target area of microsystems technology, DM54 million of which is contributed by the Federal government and DM6 million by the Land of Baden-Wuerttemberg.

The Laender have been setting up funding programs intended to make it easier for small and mid-sized companies to develop microsystems technology products. They are beginning to set up study facilities for microsystems technology at universities and colleges, and are offering additional training and further education and equipping laboratories.

Microsystems technology intersects other BMFT funding programs at a large number of points. It builds on programs which fund technology developments by combining relevant findings into systems. On the other hand, it is an obvious step to turn to microsystems technology within other programs, such as biotechnology or environmental or medical technology.

International cooperation in the field of microsystems technology is being put into practice both in bilateral projects and in EUREKA projects.

Microsystems technology was given a firm place in the fourth framework program of the European Union. This success was achieved through initiatives from science and business in a European vote. The European Union is expected to provide both support in international standardization and especially adoption of R&D target areas, for example in the development of developmental tools or the construction of foundries for the production of complex microsystems on the European level.

4.5 Information Technology and The Work Environment

The project target areas of the "Work and Technology" program provides a number of contributions to innovative, task-appropriate and applications-oriented shaping of information and communications technology and the work environment. The question of the prerequisites for the process of software development itself for the creation of applications-oriented software has been taken up in several projects investigating the process of software creation. Results led, among other things, to a reorganization of the work of developers of both standardized and individualized software. The results are being presented in the form of a guideline for software developers.

In further projects an integrated methodological model has been created for task analysis and definition as well

as for support of the user interface design for classical software systems. This methodological model, TASK, is embedded in a comprehensive procedural model which anticipates the participation and quality control by the user and at the same time integrates prototyping and iteratively adjusted development designs into a planable process. The results were presented at international and national conferences and congresses and fairs (CE BIT), and attracted much attention. Efforts towards a technology transfer to Great Britain, Belgium, Italy and Switzerland were begun.

In the project "Methods of Development and Evaluation of PROTON for Dialog Systems" (PROTOS), several practical measures to achieve an improved procedure involving later users for the development of software were worked out, including training components which create a common basis of technical knowledge for developers and users and thus make cooperation and communication easier.

Another target area was the design of knowledge processing systems and particularly of expert systems. Here the goals included supporting the work of software developers with regard to a design of their products which takes the human factor into account (EXPOSE). The development of tutorial support systems for qualification measures (e.g., expert shell D3) was initiated and is now being further financed by the EU. Several information and consulting systems, design initiatives and tools for decision support were developed and employed in several companies. Translation of the results into actual products was successful in the field of activities in CNC [computerized numerical control] machines, in medical diagnosis and in machine-tending tasks in industrial firms which manufacture paper machines.

Object-oriented programming permits the integration of new applications and modules into existing CAD nuclei. Thus in the context of the joint project "CAD Reference Model," and based on this model, knowledge bases, modelers, configurers and user interfaces can be integrated into a new system which can support a total (construction) process which must be designed afresh. Already the results of the funded initial phase of the joint project have been presented very successfully at national and international meetings.

Further important results with broad applicability address questions of providing software for branches of industry, of guidelines for task analysis, and of questions of standardized design of software products conforming to EU guidelines. The results of this and other projects are being incorporated into the work of national and international boards and institutes which bear the responsibility for regulatory measures (VDI [Association of German Engineers], DIN [German Standardization Institute], ISO [International Standards Organization], CEN [European Standards Committee], professional associations, Ministry of Labor, etc.).

4.6 Evaluation of Impact of Technology

The technical, economic and social change which accompanied information technology raised the question of the consequences of technology early on. Thus the evaluation of technological developments in a predictive and problem-oriented manner is an integral component of R&D activities for which the following framework was sketched for a predominantly "technology-induced impact of technological consequences (TA)."

- TA on telecooperation
- TA on bio/neuroinformatics
- TA on multimedia services
- TA on digital broadcasting

In the area of "problem-induced TA," particular attention is given to the impact of an increase in information-technology networking (in the business world, in the form of intraorganizational and supraorganizational networking) and whether they are compatible with competitiveness. Attention in recent activities is focussed on aspects of production and technology design, i.e., primarily on problems, analyses and experiences in the implementation of information technology using selected cases.

Telecooperation, for example, offers great hopes and opportunities; it is assumed that problems of environment, employment, time, resources and other problems can be reduced and that significant gains in efficiency can be achieved. Far-reaching systems technology solutions with audiovisual support can lead to a new level of quality in human cooperation.

Helping to shape technological change will continue to be the goal of TA. Research projects will be funded in specific fields whose urgency has become obvious based on the state of technological development or whose dissemination is obviously promising. These include, for example:

- Vulnerability and constitutionality of legally binding telecooperation; TA and design suggestions for information technology infrastructures based on the example of telecommunications services and chip cards.
- To the informed city through electronic information systems?
- Informatics theory: on TA in the field of informatics, information technology, AI and neuroinformatics.
- Expert systems and conventional data processing between application and development.
- Human models in AI and models in informatics: potentials and risks.
- Construction and application of expert systems.
- Qualification and quality control as final criterion in the development process for expert systems.

Further research projects are in preparation, e.g., on the topics of neural networks, molecular bioinformatics, digitalization of broadcast technology and possible convergences of broadcasting, telematics and multimedia.

Special significance is accorded to the contribution of information technology in the support of structural change and the safeguarding of Germany's standing. The state of research and development in each field, chances for innovation and future requirements for information technology in each field of application must be taken into account. Particular attention should be paid to aspects of information technology networking.

5. Cooperation in Europe

The initial position of the competitive situation of the European IT industry has not changed much since 1990, even though the European situation has indeed improved noticeably in parts of the field. The efforts of businesses to achieve an independent base in the fundamental technological fields of microelectronics and display technology have increased significantly: SGS-Thomson in Crolles and Siemens in Regensburg and Dresden are trying for the same share of the world market, about 11 percent, as their overseas competitors. Philips, Thomson and Sagem have founded a joint venture on research, development and production of LCD picture screens and are cooperating with German equipment and material companies.

While no new major projects have been added to EUREKA, European research policy is concentrating on the measures of the European Union within the context of the fourth R&D framework program for 1994-1998, which was passed on 26 April 1994 with total funding of ECU12.3 billion. The coming expansion of the EU, with the addition of Sweden, Norway, Finland and Austria, gives greater significance to this cooperation.

In EUREKA the benchmark projects have been and remain JESSI, DAB, HDTV and COSINE. In EU funding in the field of information technology they are the programs for funding of research and development in the fields of

—information technologies: ESPRIT

—communications technologies: RACE [Research and Development in Advanced Communications Technologies for Europe]

—telematics applications: TELEMATICS

ESPRIT, RACE, and TELEMATICS in the 2nd and 3rd R&D Framework Programs for 1990-1994

Project funding, including management and personnel costs for the commission, has been established and will be disbursed by the end of 1994 (in billions of ECU):

	2nd Framework Program	3rd Framework Program	Capital Accumulation
ESPRIT	0.933	1.352	0.180
RACE	0.311	0.489	0.065
TELEMATICS		0.380	0.050

Significant exemplary results and advances include:

ESPRIT (European Strategic Program for Research and Development in Information Technologies):

—Strengthening of the microelectronic-technology base through greater precision in CMOS technology, from 1.4 microns to 0.5 microns.

—Distribution and utilization of ASIC's by EUROCHIP (academic field) and Chip-Shop (KMU-oriented).

—Embedded microprocessors in systems of telecommunication, industrial electronics and data processing.

—Beginning of ESSI, the European Software Systems Initiative for broad utilization of software tools and solutions in all fields of business, society and administration.

—Focus on high performance computing (HPC) applications in business; application and further development of broadly distributed codes with a broad spectrum of applications.

—Founding of the European Software Institute (ESI) in Bilbao by European IT manufacturers, software companies and users.

RACE (Research and Development in Advanced Communications Technologies for Europe):

—The possibility of producing a broad-band network integrated throughout Europe was created by industry and network operators. Technical prerequisites for a pilot ATM project were completed.

—New services, such as telepublishing, teleshopping, telemedicine were opened up and demonstrated in pilot projects.

—Standards for mobile communications and video services were prepared as standardization suggestions through R&D projects (GSM [Global System for Mobile Communications], MPEG2).

TELEMATICS: The application of telematics systems made progress in the target areas of

—administration (ENS) [European Nervous System program]

—health (AIM) [Advanced Informatics in Medicine program]

—remote learning (DELTA) [Development of European Learning Through Technological Advance program]

—transport (DRIVE) [Dedicated Road Infrastructure for Vehicle Safety in Europe program]

- rural areas (ORA) [Opportunities for application and communication technologies in Rural Areas program]
- New emphases were formulated in teleworking applications and the field of the elderly and the handicapped (subprogram TIDE).
- Measures to develop a powerful European research network were linked and coordinated in TELEMATICS (Y-Net, COSINE).

The Fourth R&D Framework Program for 1994-1998

The Commission's plans anticipate a continuation of the programs relevant to information technology in the 4th R&D framework program, keeping the thematic target

areas but placing more emphasis on the interests and needs of users and consumers. The main goals of funding are:

- development of a powerful and reliable infrastructure, particularly for information and communication,
- increase in competitiveness of industry as a whole,
- improvement in quality of life.

6. Funding for Information Technology

Research and development in the area of information technology are funded in Germany by the Federal government and the Laender and within the R&D framework programs of the European Union. In 1992-93 about DM1.7 billion annually in state funds was disbursed.

State Funding of Research and Development in Information Technology, 1992-1994¹ (in millions of DM)

	1992	1993	1994
European Union ²	398	358	356
DFG [German Research Association] and Laender	231	240	250
BMFT	1,040	1,064	1,103
Total	1,669	1,662	1,709
BMFT			
Institutional Funding	405	460	454
—in GFE [large research facilities] and BLE	296	310	294
—FhG [Fraunhofer Society] and MPG [Max Planck Society]	109	150	160
Project Funding	635	604	649
—Microelectronics	169	170	198
—Informatics	87	91	92
—Base technologies	134	127	136
—Microsystems technology	97	94	98
—Production technology	148	122	125

1. Without contributions from BMI and BMPT; with freeze in EPI. 30 for 1994.

2. The average reflux quota from EU programs (2nd and 3rd framework programs and accumulation of capital for 1993/94) amount to 23 percent for ESPRIT, 25 percent for RACE and 20 percent for TELEMATICS. 1 ECU = approx. DM2.

In the Federal government the Federal Ministry of the Interior also funds research and development in the field of informatics with DM63 million in 1992 and DM60 million in 1993, and the Federal Ministry of Posts and Telecommunications funds new base technologies for communications technology with funding of DM6 million and DM7 million. The information technology industry, including DBP Telekom, contributed funds to the amount of approximately DM10 billion. In spite of a stagnating total R&D expenditure, the economy increased its efforts for research and development in the field of information technology in 1993 as well. State funding at present represents a 14-percent share of the

total national expenses for research and development in the field of information technology. Two-thirds of state expenditures were concentrated on the scientific infrastructure in colleges and state research institutes. This is in accordance with the strategic goal of strengthening the capacity of the public research infrastructure and supporting the transformation of research results into competitive products and services by funding joint projects between science and industry, with industry bearing a large share of the financing. Because of the orientation of the research activities towards application prospects with promise for the future in information technology, questions of pure basic research have a less than 20-percent share in research funding, with the total share of basic research in the BMFT at about 40 percent.

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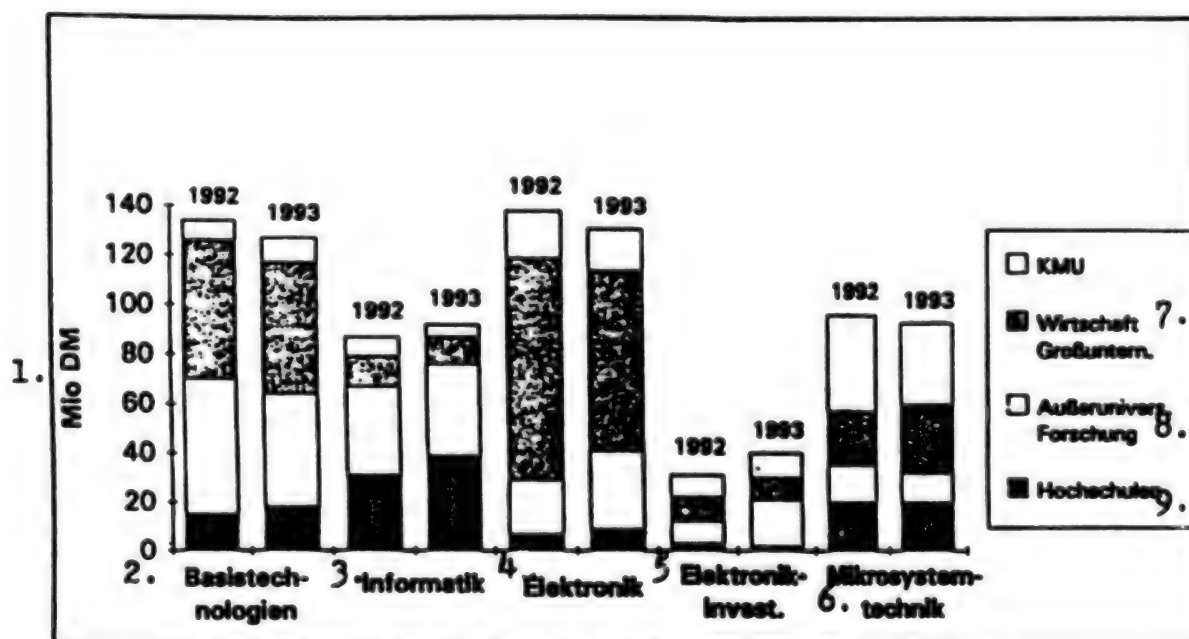
Funding for Information Technology in Major Research Facilities and Blue List Institutes¹ (in millions of DM)

	1992	1993	1994	1995
Informatics				
GMD [Society for Mathematics and Data Processing]	76.9	76.9	78.4	76.0
KFA [Juelich Research Center]	28.5	36.8	34.2	36.4
HMI [Hahn-Meitner Institute]	4.8	4.7	4.5	4.4
Base Technologies				
GMD	29.0	30.5	32.8	32.9
KFA	48.5	50.8	39.9	44.9
HHI [Heinrich Herz Institute]	14.9	15.9	16.3	16.2
FBH [Ferdinand Braun Institute]	7.6	9.1	8.6	8.7
IKZ [Institute for Crystal Growth]	4.4	5.0	5.3	8.2
PDI [Paul Drude Institute]	4.0	5.8	5.7	5.6
IHP [Institute for Semiconductor Physics]	9.7	11.7	16.4	16.7
Microsystems Technology				
GMD		1.1	1.1	1.1
KfK [Karlsruhe Nuclear Research Center]	67.1	63.2	52.9	53.6
KFA		0.9	0.8	1.2
Total	296	310	297	306

1. Without freeze in 1994; financial planning for 1995 in accordance with situation on 07/94.

Institutional funding for information technology from the BMFT rose from DM283 million in 1989 to DM460 million last year. This is caused principally by

the incorporation of research potential in the new Laender and the development of research in the area of base technologies in the research center at Juelich



Project Funding by the BMFT in the Field of Information Technology 1992-93

Key: 1. millions of DM—2. Base technologies—3. Informatics—4. Electronics—5. Electronics investment—6. Microsystems technology—7. Business, major companies—8. Non-university research—9. Universities

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(KFA) and in the central research facility on microsystems technology at Karlsruhe. The state research infrastructure grew with the foundation of the institutes for crystal growth in Berlin (IKZ) and for semiconductor physics in Frankfurt-Oder (IHP), of the Paul Drude Institute (PDI) and the Ferdinand Braun Institute (FBI) in Berlin. Institutes of the Fraunhofer Society

also turned more frequently to information technology projects, including microelectronics. Approximately 40 percent of their institutional funding is used for research in this area. In contrast, the involvement of the Max Planck Society is much lower, with less than 2 percent of their budget going to information technology (see appendix).

BMFT Budget Overview in the Field of Information Technology¹ (in millions of DM)

	1993	1994	1995	1996	1997	1998
BMFT total	1,064	1,103	1,149	1,163	1,197	1,261
Institutional funding						
—GFE, BLE	310	294	306	315	329	336
—FhG, MPG (estimated)	150	160	165	170	175	150
Project funding	604	649	678	678	693	745
Institutional funding						
—GMD	113	116	113	114	117	119
—KFA, KfK, HMI	149	126	138	146	159	163
—BLE	48	52	55	55	53	54
Project funding						
—Informatics	91	92	98	100	102	110
—Base technologies	127	136	143	144	147	160
—Electronics projects	131	134	141	142	144	155
—Electronics investment	40	64	65	59	64	70
—Microsystems technology	94	98	105	106	108	115
—Production technology	122	125	126	127	128	135

1. With embargo 1994; planning for 1995-98 in accordance with cabinet resolution of 15/07/94.

The information technology industry finances over 95 percent of the research and development it carries out. (On average, self-financing for R&D in German business amounts to 91 percent.) Only in the Japanese information technology industry does the self-financing rate reach such a high level. Here the companies benefit from tax breaks to support research and development; these expired in Germany last year.

By project finding, the BMFT also specifically supports the transfer of knowhow and efforts at innovation in small and mid-sized companies, preferably in the area of microelectronic component applications and of microsystems technology. In 1992-93, not including production technology, KMUs obtained a steady share of 30 percent of BMFT funds made available for the funding of research and development in business.

This year funding for information technology will reach a 12-percent share of the BMFT's budget. This level is to be maintained or increased in subsequent years. In a process which complements the measures of the European Union in a division of labor whose design has been voted on, the BMFT will guarantee that state funding will be optimally employed and used to achieve a closer

mesh between basic research, industrial basic research and translation of results into practical applications.

In accordance with the goals of the fourth R&D framework program of the European Union, the following three specific programs for 1994-95 are being made ready for the funding of research development and demonstration in the field of information technology:

- information technologies (ESPRIT): 1,911 million ECU
- communications technologies (ACTS): 630 million ECU
- telematics (TELEMATICS): 843 million ECU

With a total of 3,384 million ECU, information technology will obtain a 27.5-percent share of the fourth R&D framework program of 12.3 billion ECU. Facilities in Germany have received an average over the past few years of 23 percent of EU funds in the ESPRIT program, 25 percent in RACE/ACTS and 16 percent in TELEMATICS; about 70 percent of these funds go to commercial businesses, one fifth of them for small and mid-sized companies.

Appendix

Contributions of non-university state research institutes

A1. Max Planck Society

In the Max Planck society, several institutes are working on problems which are covered by the information technology funding plan:

Max Planck Institute for Informatics in Saarbruecken

The institute began work in December of 1990 and currently consists of two divisions. In the "Algorithms and Complexity" division, headed by Prof. Mehlhorn, efficient algorithms and data structures for the solution of complex algorithmic problems are investigated. Decisive contributions have been achieved in the development of superfast algorithms for parallel computers. There is also great practical value in the approximation algorithms developed in the field of motion planning for robotics and the design of chips for the exact summation of floating decimals. The LEDA library (Library of Efficient Data Types and Algorithms) for combinatorial calculations established by the institute is now used all over the world. The library is used in several hundred academic and industrial groups as the basis for the development of algorithms. In the "Programming Logic" division the experimental work deals with the planning and creation of translators and program development systems. One notable result of the research is the development of translation mechanisms which translate speech forms (e.g., "knows that . . .," "wants to . . .") into normal predicate logic. These mechanisms are the basis for systems development where the objective is automatic production of natural-language dialogs.

The Max Planck Institute for Informatics supervises the working group "Error-Tolerant Computing" of the MPG at Potsdam University, which deals with the design of self-testing and self-evaluating circuits. Through a combination of error recognition circuits and self-tests and through optimal adaptation to concrete error models, it was possible to improve the error recognition properties of previously known processes by several orders of magnitude.

The following Max Planck Institutes are also working in subfields which touch on objectives of the funding plan:

In the Max Planck Institute for Solid State Research in Stuttgart, the focus of the work is on III-V semiconductors, semiconductor nanostructures, optical and electronic properties of new components, high-temperature superconductors, chemical sensors and solid-state ion conductors. The institute supervises the MPG working group "Theory of Dimensionally Reduced Semiconductors" at the Humboldt University in Berlin, which deals among other things with the theoretical treatment of two-dimensional charge carrier movements in so-called "quantum troughs." Researchers have succeeded in formulating a reliable theory of lines in the optical spectrum

of such semiconductor structures which can be well-confirmed experimentally. This theory makes it possible to deduce the quality of the layered structures directly from the spectra.

At the Max Planck Institute for Metal Research in Stuttgart, the subinstitute for physics is dealing with high-temperature superconductor layers. A procedure has been established using ion feedback scattering which makes it possible to determine both the thickness of the layer and the relative concentrations of the metallic components of the superconductor from the spectrum of scattered ions.

At the Max Planck Institute for Radioastronomy in Bonn, work is being done on the development and testing of SIS (superconductor-isolator-superconductor) diodes for a planned radiotelescope in earth orbit (FIRST: Far Infrared and Sub-Millimeter Space Telescope).

At the Max Planck Institute for Brain Research in Frankfurt research is being done in the neurophysiology division on neural networks. One problem for which a solution has been found is the assignation of characteristics in the simultaneous representation of several objects in an artificial neural network.

The project topics of the Max Planck Institute for Psycholinguistics in Nijmegen include computer simulation of visual and auditory word recognition, a process which plays a decisive role in speech comprehension. With the help of an interactive model, results have been achieved which correspond closely to the data for human test subjects.

At the Max Planck Institute for Biochemistry in Martinsried, the membrane biochemistry division is working on the bacteriorhodopsin molecule, with the help of which so-called halobacteria transform light energy into electrochemical energy. A central component of this molecule changes its structure when light strikes it, taking on a yellow color. Only when the energy has been passed on is the original structure and thus the original color (violet) restored. This meant that scientists had come across a biological system which indicated by color change whether it had stored energy or not. This effect, which was discovered by chance, opened up the possibility of using the color change for the storage of optical information. The bacterial dye which was optimized jointly with scientists from the University of Munich is now considered a highly suitable material for optical image processing, and offers solutions for the problem of pattern recognition which had eluded scientists for a long time. Prof. Oesterheit was recognized for these research projects by the Karl Heinz Beckurt research prize and the Philip Morris research prize.

The Max Planck Institute for Extraterrestrial Physics in Garching is investigating how concrete information about observed objects in the universe can be obtained using processes from nonlinear dynamics on modified cosmic signals. The method, which has a patent pending,

is now being tested in collaboration with doctors from Munich Technical College to see if it is suitable for providing a means of early diagnosis of heart attack risks by computer analysis of electrocardiograms.

The total expenses of the Max Planck Society in this field, excluding the Max Planck Institute for Plasma Physics, where the informatics division is concerned among other things with "scientific supercomputing," amounts to about DM20-25 million annually, or about 1.5 percent of the total budget of the Max Planck Society.

A2. Major Research Facilities

Society for Mathematics and Data Processing (GMD)

The reorientation which began about 2 years ago had as its goal an increase in the level of direct effectiveness of R&D projects in application fields which are primarily knowledge-oriented. This orientation is guaranteed by direct involvement of users in the definition and execution of the projects. A large proportion of the necessary expenses is covered by endowment financing. About a third of GMD funds goes to projects with users and industry. A further form of cooperation is planned with the setting up of a technopark in which cooperative partners can settle in immediate proximity to one another. Negotiations with a Japanese manufacturer and a mid-sized German company were successfully concluded.

The high respect which GMD scientists and their work command is reflected on the European level in the number of applications for the second ESPRIT III prospectus which have been granted. In contrast to an average EU success rate (applications approved or in close competition) of 31 percent, GMD applications achieved a significant 57-percent rate.

The establishment of a new organizational unit, "Media and Communications," set the course for an active and more comprehensive public role. It is no longer oriented only towards experts, but presents research results in many forms to a broad public, in order to promote the idea of "innovation through research" among the citizens and thus give visible evidence of its usefulness.

Concentration on four research target areas, together with structural improvements, created the conditions for achieving the above-mentioned goals. In spite of stagnating or even decreasing research funds, good results were obtained.

Under the research target area of design processes, the GMD has taken up new theoretical approaches to the integration of microelectronic and micromechanical systems and successfully developed them in cooperation with partners from industry and science. Joint integrated design of hard- and software plays a key role in this field. It leads to so-called imbedded systems, which reappear in applications for telecommunications, robotics and control technology. The institute provides engineers with an

environment in which they can integrate new tools into the design system. The results obtained with their cooperating partners were tested in prototypes. The efficiency of the procedure was demonstrated in the filing of four patents, two of them in the field of fuzzy logic.

Projects on the adaptation of pre-existing software to new conditions (re-engineering) were so successful that a contract from a large software house is expected in the near future. The use of newly developed simulation tools for the application area of microsystems technology is already widespread in mid-sized companies.

Cooperation in the Japanese RWC program led to the development of two-armed robots capable of learning which can adapt themselves to new tasks with a large degree of independence on the basis of "genetic algorithms." The EUROCHIP initiative, in which more than 300 European universities are participating, is being supported with advice, services and education.

The development of real-time image processing systems on parallel computers, of multimedia data banks and the corresponding teleservices, for which a large market is already emerging, are the object of a number of projects in the research target area "Intelligent Multimedia Systems."

In the "Visualization and Media Systems Design" project, which is independent of the institute, the course was laid out for future projects in the field of scientific visualization and its multiple uses in meteorology and robotics, but above all in medical technology. Basic projects in the field of weather forecasting were supplemented with a visualization of data integrated into the simulation process, which made an impressive debut at the 1993 conference. For multimedia author and retrieval systems, new data bank systems and design tools were developed which could do justice to the large quantities of data to be stored and the complex interconnections between the individual informational items. Artificial intelligence procedures were developed and tested for semantic analysis of multimedia contents. A model of a virtual office was developed as a prototype. Within it, users can move, communicate via video links and cooperate through common processing of electronic documents.

Significant progress has been made towards making the future wide-band ISDN (Integrated Services Digital Network) a reality in the research target area "Communications and Cooperation Systems." For instance, the standards for ATM (asynchronous transfer mode) technology itself, for the ATM adaptation layer and for signalization in ATM networks were agreed on. The experience gained through early practical use of ATM technology made it possible to create a special adapter between various workplace systems and the ATM network.

Numerous security functions are offered to users on a cryptographic basis with an public-access software package and can be transferred to individual systems, for

example an integrated access to X.500 directory services or chip card personalization function. With BMI, DETECON [German Telepost Consulting] and the Kienbaum business advisory board as partners, an investigation was made in a study of the IVBB [Innovative Bonn-Berlin Datalink] about how functionality and cooperation in the division of work between Berlin and Bonn can be assured using modern methods and procedures of communicative and cooperative support.

In the POLIKOM project, which is independent of the institute, the prerequisites for systems technological integration of telecommunications, information and multimedia technology into a comprehensive telecooperation and telepresence technology were investigated and tested. The requirements for simple, well-priced and environmentally friendly solutions were studied and users were supported in producing innovative systems solutions in close association with partners from industry.

In the research target area "Parallel Computing," substantial contributions to computer architecture, to the development of hardware and software and of rapid numerical and discrete algorithms for central applications in the natural sciences and technology have been achieved. In bioinformatics, new scientific ground was broken with the development of discrete models and algorithms. The GMD has made significant contributions to the planning of the BMFT funding programs on parallel supercomputing and on bioinformatics.

Research results from the field of number theory have earned three scientific prizes. In the parallelization of existing software a spectacular breakthrough was achieved: the European program on mid-range weather forecasting is running on all currently available parallel systems on the basis of the newly developed portable programming interfaces.

In the major EU project EUROPORT, in which 25 important industrial programs are to be introduced portably over the next two and a half years into all parallel systems, scientists involved with this research target area are engaged in management, in technical support of the partners and content-based work.

In the field of molecular bioinformatics, a project each on protein structure prediction and on the calculation of receptor-ligand interactions has been initiated. This has provided a sturdy basis for establishing this new research orientation permanently in the GMD. Research work has begun in both projects with the development of plans for new algorithms.

Juelich Research Center (KFA)

In the field of information technology, excellent results were obtained both in semiconductor technology and in superconductor technology. The selected examples presented here show clearly that the institutes which joined

to form the "Program for Basic Research in Information Technology" (PGI) of the KFA are assuming a leadership role in many fields.

The most rapid transistors in information technology are based on III-V compound semiconductors, most of which are made of GaAs and GaAlAs. In optoelectronic components InP and GaInP materials systems also come into play. It has now proved possible to increase the mobility in this materials system in quasi-two-dimensional electron gases at temperatures below 50°K by more than a factor of 2 to over 450,000 cm²/VS. These reproducibly high mobilities make even greater switching rates for the transistors possible. Something similar has also been achieved in Si-Ge technology. The record values obtained for mobility in quasi-two-dimensional defect electron gases also open up new prospects for electronic components.

Porous silicon is a component of the activities which an optoelectronics based on silicon contains. The high quantum efficiency of the electroluminescence of porous silicon promises the production of the first optoelectronic components in the near future, particularly the idea of a porosity lattice and of complex porous layer systems, has attracted attention among professionals. The potential for future applications ranges from optical filters to wave conductors which can be integrally deposited on a silicon chip together with detectors and amplifiers.

In superconductor technology, dielectric resonators with shielding have been developed for the microwave range from thin high-temperature superconductor films. Such resonators demonstrate extremely sharp resonances with quality factors above 500,000 and are therefore a key component for oscillators with low phase noise. The use of low-noise oscillators makes it possible, for example, to improve the properties of radar systems. High-frequency oscillators based on high-temperature superconduction/Josephson contacts are the object of a project funded by the BMFT (DM827,000).

Another application for which the KFA plays a leading role internationally is the development of quantum interference detectors (SQUIDs) based on high-temperature superconductors. Their extremely high sensitivity when compared with magnetic fields has made it possible to measure magnetic signals from heart or brain activity. Measurements of heart activity without bulky magnetic screening have already been achieved using the plan developed in the KFA. In addition, it was possible to demonstrate their suitability in non-destructive material testing, e.g. in the investigation of tensile concrete components. The development of SQUIDs is based in large part on joint projects with industrial participation (Siemens, Daimler Benz) funded by the BMFT. The funding amount for biomagnetic metrology was DM2.24 million and for non-destructive material testing DM287,000.

In the field of the further development of magnetic layering systems for data storage, we should point out the

oscillating magnetic coupling between layers separated by non-magnetic layers, which was discovered here. An unusually sensitive magnetoresistive sensor can be developed on this basis; its application possibilities are not limited only to use in data storage. In addition, new procedures for ultra-high-resolution imaging of magnetic domains for the investigation of magnetic storage media have been developed. They are based on the spin analysis of secondary electrons in an electron scan microscope or on magnetic screen power microscopy. The development of new technologies to investigate nanomagnetic properties is funded by two EU projects (DM355,000). Furthermore, there is a European study on the use of multiple layers in magnetoresistive sensors in which Siemens, Philips and Thomson-CSF, among others, are participating (DM298,000).

Finally it remains to be stated that a constant evaluation of the results with respect to their prospects for application is taking place. This consists, for example, of the filing of patents (e.g., electronic components, non-destructive material testing, porous layering systems), in order to protect the knowledge gained by patent law and to make it available to German industry through licensing. In the field of basic research in information technology there have been more than 30 inventions for which patents have been filed.

The research results described above show that the program "Basic Research in Information Technology" and the institutional funding connected with it have contributed to strengthening the position of German research. The close links between institutional and project-oriented funding, for instance, have made the Institute for Layer and Ion Technology a worldwide leader, e.g., in the field of the manufacture and use of SQUIDS.

Since the institutional funds are no longer adequate after the cuts of the last few years to finance top research on an international level, the attempt was increasingly made to obtain funds from a third party. It would be desirable if funding plans could be adapted more rapidly to new trends. This is true of the field of silicon-optoelectronics (erbium, porous silicon, silicon-germanium) and for applications of high-temperature superconductors. A distinction should be made in high-temperature superconducting between signal processing (ultra-high frequencies up to 1 THz) and sensorics. It is in sensorics that a market for SQUIDS is opening up because of the three application area (medicine, non-destructive material testing, geology) which can only be assured by focused funding measures.

Central Research Facility at Karlsruhe (KfK)

In December 1992 the microsystems technology project was set up in the KfK. On the one hand, the goal of the project is to conduct long-term precompetitive research on microsystems technology and to continue to develop this technology and work out new procedures for it. On

the other hand, the results of R&D projects are constantly to be translated into marketable products. For this purpose cooperative agreements are made with potential industrial users in order to be able to react appropriately to their challenges and requirements, and increasingly developmental contracts are carried out directly for industry.

A number of important advances have been achieved in the project to date.

The efficiency of microstructuring using the LIGA process was significantly increased. Even the complex structures which are required for many technical applications have been produced by now (conic and stepped structures, bridge structures). The range of structurable materials (metallic alloys, high-efficiency plastics, ceramics) was expanded. The introduction of LIGA technology and of individual products made with it into the marketplace is being taken over by the company microparts GmbH in Dortmund, the licensee of the KfK for the LIGA process.

Other processes for microstructuring (mechanical microproduction, laser processing, optical lithography, structuring with particle beams, etc.) were further developed and used for new application fields. With mechanical microproduction, microcoolers and microreactors were developed which are being tested by industrial partners in view of their numerous application possibilities.

Various chemical sensor principles are being miniaturized for the purposes of inexpensive mass production. Functional models of optochemical and surface wave sensors were introduced. Numerous companies have declared their interest in a business application. Microactuators based on various physical principles (electrostatic, electromagnetic, fluid, thermopneumatic actuators) were manufactured and their principles successfully demonstrated. Procedures for the creation or processing of functional materials ("smart materials," such as alloys with form memory, magnetostrictive and piezoelectrical materials) were developed in order to tap their potential as sensor and actuator elements.

A system for computer-assisted mask adjustment is now being used routinely in LIGA beaming and is to be integrated by a commercial producer into his program. A system for the optical measurement of complex microstructures (quality control) has been developed to the point where it can be transferred to industry. Tools are being developed for the simulation of the various steps in the LIGA process in order to make it possible to carry out the computer-assisted design of microsystems.

In order to do justice to the increasing variety of materials and complexity in the integration of microsystems, construction and linking techniques are continually being improved. For example, membrane pumps were manufactured with components which were made with molding and membrane technologies and are so linked with one another by a specially developed adhesion

technology that it is already possible to produce them economically. In the quasi-monolithic integration of LIGA components with microelectronics it has been demonstrated that the molding technology used does not have an adverse effect on the capacity of the microelectronic circuit.

For application in minimally invasive surgery (MIC) a large amount of operating instruments and equipment was developed and tested in accordance with the requirements of clinics. Negotiations are being conducted with several companies on marketing these devices. The 3-D video endoscope developed in the KfK is already being operated by a mid-sized company. The industrial partner was awarded the innovation prize for German business in 1994.

In order to make its ability to produce complex microsystems clear, the project defined protoypical microsystems ("demonstrators") when it was instituted, which it wished to present by the end of 1995 as functional models (3-D accelerator sensors, optical switcher, optical toxin analyser, SAW sensor system for the detection of toxic organic gases, electrolyte analyser, experimental telemanipulator for use in MIC). Along with the further development of technologies which lead to applications, the main criterion for defining the demonstrators was the potential for cooperation with industry.

Within the context of the microsystems technology project the KfK is working very closely with industrial partners. By now more than 30 percent of project activities are being carried out in the context of industrial cooperation and industrial contracts. The KfK is cooperating in four BMFT joint projects (METEOR, MINOP, AVT-KEO, MST-UEM), and is attempting to put its knowledge and abilities to work within the context of the new BMFT program as well. Specific suggestions or contributions have been worked out and presented for two projects.

With more than 30 universities and other research facilities, many of them outside Germany, there are close contacts with new developments and business applications of microsystems technology. The KfK participates in four EU projects (MICS, MAGNIFIT, COMET, HMC).

A3. Fraunhofer Society (FhG)

The Fraunhofer Society conducts applied research and development in applied engineering, with the goal of strengthening the position of the economy in Germany. Based on endowment and project-financed preliminary research, effects in the economy are produced by contracts from business, spin-off company foundations, demonstration centers and training. In the old Laender those working with information technology include the IGD [FhI for Graphic Data Processing, Darmstadt], IITB [FhI for Information and Data Processing, Karlsruhe], LAO, IFT [FhI for Solid-State

Technology, Munich], IMS [FhI for Microelectronic Circuits and Systems, Duisburg], IIS [FhI for Integrated Circuits, Erlangen], ISiT [FhI for Silicon Technology, Berlin/Itzehoe] and IAF [FhI for Applied Solid-State Physics, Freiburg]. In addition, institutes with project target areas in manufacturing technology, production technology or logistics in subfields are making contributions to information technology.

The capacity to develop information technology products and processes in the old Laender (excluding defense) grew in the years 1988-1993 in the above-mentioned institutes, keeping pace with the market, from 675 to 885 jobs. Running expenses were DM152 million in 1993, with contracts from industry amounting to DM46 million. In the course of German unification the FhG founded the IMS2 [FhI for Microelectronic Circuits and Systems, Subinstitute Dresden], ISST [FhI for Software and Systems Technology, Berlin] and IZM [FhI for Reliability and Microintegration, Berlin] as well as the divisions EAS [FhI for Integrated Circuits—branch office (Ast) for Automation of Circuit and System Design, Dresden] (of the IIS), EPO [FhI for Information and Data Processing—Ast for Process Optimization, Berlin] and EPS [FhI for Information and Data Processing—Ast for Process Control, Dresden] (of the IITB), and EGD [FhI for Graphical Data Processing—Ast Rostock] (of the IGD) in the new Laender, with a total capacity of 270 jobs. There is a total of 1,115 workers doing research in the field of information technology in the FhG.

Research results with promising applications in business are as follows:

In the IIS a procedure for data reduction in the transmission and storage of tone signals without audible loss in quality was developed, e.g., for digital broadcasting (DAB). This tone-coding procedure, the most powerful available at the moment, makes a decisive contribution to the ISO-MPEG standard.

Analog-digital converters (ADU) are key components of information technology systems. The IIS developed and produced a 5-bit ADU with a search rate of 3.6 GHz together with the IAG. At present work is being done on a 10-bit ADU with 200 MHz.

In the context of the research target area of photonics (cf. 4.2.5), the LAF has developed optoelectronic integrated circuits (OEICS) for demonstrating an optical high-bit-rate information system with data rates of up to 20 Gbit/s. The next goal to be attempted in cooperation with industry is 40 Gbit/s.

The IGD developed rapid integrated circuits for high-resolution 3-D graphics (HRDC) within the JESSI framework in cooperation with the IIS. The IGD is working on evaluation and hardware-appropriate conversion of the relevant algorithms. The first prototypes will be produced by the end of 1994. Further innovative projects of the IGD deal with the visualization of technical/scientific data.

A passenger vehicle with independently developed computer systems for machine image evaluation was tested by IITB-IV in a systematic investigation of driver-vehicle interaction in the development of vehicle-autonomous systems for driver support depending on the traffic situation. The vehicle is capable of autonomous trips under experimental conditions with its automatic axial and lateral drives supported by a visual system.

In the IITB-DV an object-oriented process control system was developed (PROVIS) which is already being used in industry. The advantages of object-oriented control technology are in the sensible and practical division of process imaging into decentralized partial process images and in the support of graphical user interfaces. With PROVIS a reduction of projection expenses by about 80 percent is attainable.

A robot system is being developed within the BMFT project SENROB. The IMS built a neuroprocessor chip for it which is being used as an essential element in a parallel multiprocessor network.

At the IMS in Dresden the prototype of a portable voice reading device for the blind and visually handicapped based on speech synthesis processors they developed themselves was produced. The basic competence achieved in acoustic signal processing has since led to follow-up projects, e.g., for TMC transport radio or a PCMCIA [PC Memory Card International Association] speech synthesis card.

In the JESSI flagship project IVPS (Integrated Vacuum Processing System) Measuring and regulating processes are being integrated into a new, highly standardized system for microelectronics manufacture at the IIS-B.

Within the BMFT microsystems technology funding program, the ISIT has developed a biosensor for detecting glucose and lactates. It has obtained reproducible results in the laboratory with record survival times in the blood of about 100 hours.

The IAO has made advances in the design and manufacture of graphical user interfaces (GUI) which make them capable of working together with general CASE (computer-aided software engineering) tools. The necessary cost of programmers can be reduced to about 10 percent of previous expenses for GUI adaptation by the new tools.

The examples come predominantly from the field of applications-oriented basic research or applied research. The relevant projects are financed by institutional funding or within joint projects with the BMFT and companies. In addition, the Fraunhofer institutes cooperate with individual clients of mid-sized industry for information technology assignments, using a range of developments of various orders of magnitude. The achievements of the FgH extend to product development and small-scale production. This cooperation between

the FgH and KMU's occurs mainly with regional businesses and thus makes a significant contribution to structural change in individual economic regions.

A4. Blue List Institutes

The facilities of the "Blue List" are financed by the Land where they are located as partners and by the Federal government at 50 percent each.

Heinrich Hertz Institute for Information Technology (HHI)

The HHI concentrates on the focal topics of photonics and electronic imaging technology. The long-term goal of photonics is the optically transparent network. Developments and investigations of processes and components for purely optical signal processing are carried out in the transport level of wide-band communications systems. The joint research program Photonics I, which runs from 1990-1994 (cp. 4.2.5), is being carried out together with partners from industry and science by two groups, Optical Signal Processing and Optical Linking Technology. The HHI will also play a decisive role in the Photonics II research program (1994-1998).

The long-term goal of electronic imaging technology is a system for the reproduction of real or synthetic scenes according to desired standards of quality using digital signal processing and transmission. Projects on this topic are oriented towards the establishment of base technologies for different image services. These base technologies can be divided into the fields of signal processing, display technology and adaptation of electronic image systems to human perceptual properties. An important part of the projects is being carried out within the joint project Hierarchical Digital Television Transmission (HDTV-T) (see also 3.1). Furthermore, an alternative to flat liquid crystal screen is being investigated in the HHI in the field of electroluminescence. Basic parameters are being investigated to find out whether ELD's can meet the requirements for large-screen color TV (see 4.2.6).

Ferdinand Braun Institute for Ultra-High Frequency Technology in the Research Group Berlin e.V. (FBH)

The FBH is conducting applications-oriented basic research in the field of modern communications systems which are based on microwave and optical frequencies. New, innovative component technologies are necessary. Along with extensive possibilities for computer simulation of electronic circuits, the FBH has a complete clean-room process line for the material system of III-V semiconductors at its disposal for practical production of the ideas developed. In addition there are plans to establish a "center of competence" in the field of gas-phase epitaxy in the not-too-distant future.

The FBH was founded on 1 January 1992 on the recommendation of the Science Council as a Blue List institute. Particularly close cooperation with industry is

anticipated, i.e., part of the personnel is to be financed, e.g., through industrial contracts for a time.

The institute has now been incorporated into the BMFT activities of the funding plan. This was achieved partly by targeted project funding as "start-up assistance" and partly by joining with pre-existing joint projects of the BMFT.

Institute for Semiconductor Physics (IHP)

The research of the IHP is oriented towards the integration of single-crystal SiGe layers into silicon technology with the goal of creating the foundation for a more highly integrated, rapid and multifunctional silicon-based microelectronics for information technology.

Applications-oriented basic research is being conducted and work is being done in the fields of SiGe semiconductor physics, diagnostic methods, process technology and design and simulation of test structures of classical and nanoelectronic physical principles. The institute has a complete silicon laboratory line at its disposal for the preparation of silicon wafers for these investigations.

The institute has achieved internationally recognized research status over the past two years.

In research and teaching the institute is cooperating closely with the University of Cottbus and with national and international facilities.

Paul Drude Institute for Solid-State Electronics in the Research Group Berlin e.V. (PDI)

The PDI is conducting research projects on low-dimensional solid-state structures which are predominantly theoretically oriented. The main interest at the moment is centered on compounds produced from the elements of the third and fifth major groups of the periodic table. Modern methods of layer production with precision in the atomic range in connection with structuring technologies on the nanometer scale make possible not only the manufacture of traditional three-dimensional component structures but also the defined

production of so-called dimensionally reduced structures. With these structures, quantum mechanical effects which could only be predicted in theory before can be experimentally verified—e.g., the effects which electrons in zero-, one- and two-dimensional space should display. These phenomena may form the foundation for completely new component technologies.

The PDI, which was formally founded on 1 January 1992 on the recommendation of the Science Council as an institute of the Blue List, is still taking shape at the moment, but was already able to claim an impressive number of publications in the international scientific press in its 1993 annual report.

Institute for Crystal Growth in the Research Group Berlin e.V. (IKZ)

In interdisciplinary research, the institute is investigating the basis for the growth and characterization of crystalline materials. The choice of research target areas is oriented towards the application of material in information technology, power electronics, photovoltaics, sensorics, optics and basic research.

The spectrum of achievements extends from applications-oriented basic research and the development of technologically applicable growth procedures to the development and preparation of crystals for other research facilities and for industry. The following materials are central:

- silicon
- gallium arsenide
- indium phosphide
- II-IV compounds
- oxide crystals

The institute, with about 50 employees and with 30 colleagues funded by third parties, is cooperating closely in research and teaching with university and non-university facilities in Germany and abroad.

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